LITHIC EXCHANGE AND PRODUCTION ON ANDERSON MESA,
NORTH CENTRAL ARIZONA

by

Gary Martin Brown

A Publishable Paper Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Arts

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ABSTRACT

The anthropological literature on social and economic interaction indicates considerable diversity in the modes of production and organizational complexity of human societies engaged in interregional trade. Because of such variability archaeologists who fail to analyze prehistoric exchange in the context of socioeconomic organization, and especially those who equate idealized types of exchange with "levels" of organizational complexity, can provide only limited explanations of cultural change. A systemic perspective on exchange, production and social organization is defended in this paper and substantiated with archaeological data from the "Classic Pueblo" horizon of the American Southwest. Organizational characteristics of exchange and production measured in lithic assemblages from 31 sites in north central Arizona show a greater degree of productive specialization than might be revealed by qualitative analysis of formal and stylistic variability.

Two contrasting evolutionary models for the rise of nucleated settlements are tested. A model of craft specialization and exchange caused by population nucleation and the development of administrative hierarchies is rejected by demonstrating that centralized obsidian procurement and production preceded the emergence of large nucleated villages in the study area. Evidence of intraregional specialization and centralized trade prior to nucleation favors the alternative model in which specialized exchange and production are factors in explaining the appearance of large complex settlements. The association of lithic craft specialization and centralized obsidian exchange offers empirical support for the argument that trade and production are related systematically.
ACKNOWLEDGMENTS

This paper was written in lieu of a M.A. thesis under the guidance of my supervisory committee, Drs. Fred Plog, James Schoenwetter and Alfred E. Dittem, Jr., serving as chair. Dr. Dittem aided immensely in the laboratory analysis and shared his thoughts and knowledge of the archaeology and geology of the Mogollon Rim region with great generosity. Dr. Plog provided me with the opportunity to work at Chavez Pass and to initiate my own research project in the Anderson Mesa area, providing me with lab assistants for the lithic analysis. In addition to my intellectual debt to all three committee members, I am especially grateful to Dr. Steadman Upha for his encouragement and input in various aspects of the research, Dr. Sylvia W. Gaines for her patient assistance in the codification, management and manipulation of the large lithic data base; Peter J. Pilles, Jr., for consultation on matters of prehistory and research using archaeological resources in the Coconino National Forest; Debra Foldi for sharing unpublished papers on lithic resources and artifacts in the study area, and for her unfailing support; and for their diverse contributions: Neal W. Ackerly, William E. Davis, Warren R. DeBoer, Frank J. Findlow, Margerle Green, T. Kathleen Henderson and Phil C. Weigand.

Field research was carried out with the cooperation of several individuals and institutions. Investigations at Chavez Pass have been funded primarily through a Basic Research Grant from the National Science Foundation to Drs. Fred Plog and Charles F. Herbs. Support for the Lithic Exchange and Production Study was provided by the Research and Development Committee of the Department of Anthropology, Arizona State University. Many good friends volunteered to help surface collect sites:

Carla Burnside, Bill Davis, Debra Foldi, Steve Kalasz, Brian Kenny, Jim Kirkland, Barbara Macnider, Anne McKibbin, Shelli Nelson and Margaret Van Ness. Fieldwork was done under permit from the USDA Forest Service, administered by Peter Pilles. While I acknowledge my responsibility for any errors or shortcomings of the study, all of these people share the credit for its accomplishments.
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INTRODUCTION

The investigation of prehistoric exchange has attained increasing prominence in archaeological research during the last decade.¹ There are both methodological and theoretical reasons for the rather sudden interest in trade. While technological advances have contributed enormously toward the development of methodologies to document exchange, much of the methodological research has itself stemmed directly from theoretical shifts which have stressed the significance of social and economic interaction in understanding processes of human adaptation and long-term cultural change. Functional relationships between systems of economic exchange and production, though very important in some theoretical equations,² have not been examined effectively in archaeological studies of trade. Very few archaeologists have attempted to wrestle with exchange and production simultaneously, despite recognition that exchange patterns cannot be fully understood without knowledge of production.³ The exact content of prehistoric exchange systems—for example, raw materials or artifacts—and the mode of production that supplied the distributional system rarely are specified in archaeological situations. Yet few anthropologists would dispute the theoretical significance of exchange and production, and especially institutions that integrate systems of exchange and production, in explaining sociocultural evolution.

My objectives in this paper include a methodological effort to more completely describe systems of exchange and production; I also attempt to explain the interrelationship of the two and their effects on organizational change. The gap in our knowledge of prehistoric exchange and production will not be bridged by new techniques or methods of analysis, but through implementation of research designs concerned explicitly
with the functional articulation of exchange and production. The present study is aimed at describing the role of specialized production and trade of material culture in the formation of nucleated communities in the Colorado Plateau physiographic province of the SW United States. The inquiry is intended to provide substantive information relevant to a more general set of questions identified in the research design for archaeological investigation of the Chavez Pass district, a program which seeks to explain the growth and abandonment of a complex settlement system centered at Nuvakwewetaq (Chavez Pass Ruin). Thus, my goal is to assess the explanatory potential of productive specialization and trade as variables in evolutionary models of the development of complex societies.

The effects of productive specialization and interregional trade on nucleation in the Plateau Southwest have been treated in depth in two recent studies which suggest the importance of the two factors in the emergence of organizational complexity in the Puebloan area. This position is supported by a number of analyses of decorated pottery which suggest the presence of specialized tradewares having localized source areas but broad archaeological distributions due to widespread exchange. A similar argument is developed in this paper. I present data derived from lithic remains, a class of material culture not rigorously treated in the literature on Southwestern craft specialization, and demonstrate the relevance of this information to the testing of models explaining the growth of centralized settlement systems.

RESEARCH ORIENTATION

Since 1977, Arizona State University has conducted archaeological investigations in the Chavez Pass district, a complex prehistoric settlement system above the Mogollon Rim in north central Arizona (Fig. 1). The largest site in the area, indeed one of the largest in northern Arizona, is known as Nuvakwewetaq, previously referred to as Chavez Pass Ruin and Nuvuequetaka. The site complex includes three massive pueblos, a number of smaller roomblocks and single room structures, shrines, plazas, walkways, and other extramural features.

Excavations in the southern part of the complex, known here as the South Pueblo, have shown that the two southern roomblocks and most of the associated remains represent an intensive occupation during the 14th and 15th centuries A.D. Over 500 ground floor rooms have been mapped on the South Pueblo, while excavations have shown that the roomblocks were constructed in tiers ranging from one to four stories in height. Integration of surficial mapping of architectural remains and test excavations indicates an estimated 950 rooms in the South Pueblo complex. A conservative estimate of contemporaneous population is between 1500 and 2000 individuals, with a likely maximum between 2500 and 4500. Excavations in the North Pueblo indicate a series of non-contiguous roomblocks consisting solely of single story buildings. These are much less apparent on the ground surface than the South Pueblo ruins and considerably less amenable to surficial mapping. An estimate of 100 rooms is likely to be highly conservative. Much of the associated deposits are earlier than those on the South Pueblo, but a significant period of temporal overlap between the northern and southern parts of the site complex can be inferred from the chronological data currently available.
Survey of the Chavez Pass district has revealed a classic pattern of population aggregation. Both the number of sites and their size increased between 700 and 1150 A.C., followed by continual growth in site size but a decline in the number of sites. Nuvakwet'ataq'a, situated in the middle of Chavez Pass, was probably the largest village in the district by 1200 A.C. Occupation of the hinterland was shrinking considerably by this time. At Nuvakwet'ataq'a, however, the intensity of human activity as reflected by artifact counts and architectural remains increased until the 15th century when the whole area was deserted. The demographic pattern associated with the period of nucleation is not yet sufficiently clear to be viewed in a regional perspective. While comparable surveys have not been undertaken in neighboring areas, a similar pattern of aggregation is apparent to the NW at Anderson Pass, also culminating in the construction of two large multistory pueblos, Kinnikinick and Grapevine, about 15 km. from Nuvakwet'ataq'a.

The trend toward nucleation and the establishment of "great towns" has been observed in many parts of the Anasazi area, and elsewhere in the Southwest, being the hallmark of the "Classic Pueblo" horizon of the first half of the second millennium A.C. Explaining the development and collapse of these population centers has a long history of debate among Southwesternists. The controversy surrounding the two processes is extensively covered in the Southwestern literature and need not be reviewed here. Of interest in this article is the role of specialized production and exchange of material culture in the development of such centralized settlement systems.
MODELING ORGANIZATIONAL CHANGE

Southwestern archaeologists have traditionally assumed organization of production at the household level, an assumption at odds with increasing evidence that few, if any, prehistoric pueblos could have possibly functioned as autonomous units. The most recent explanations of Puebloan adaptation emphasize the need for sedentary populations through time. Though the degree to which particular options were exercised varied through time and from place to place, it would appear that regional adaptations included pooling of risks through redistribution and other forms of exchange, and migration when localized fluctuation stressed the subsistence base beyond the limits of buffering strategies.

Most anthropologists acknowledge the relevance of differentiation, specialization and communication within and among regional populations to understanding sociocultural evolution. Whether these factors are more cause or effect of organizational complexity is less certain. Arguments supporting the former position emphasize environmental diversity leading to intraregional specialization and local exchange under conditions of sedentism. A second aspect of the problem of resource variability to which human populations frequently adapt through exchange is environmental perturbation. Stressing the function of trade in alliance formation, it has been argued that, in the absence of natural diversity, intraregional specialization and exchange of artificially localized products may develop as a social mechanism for mitigating intervillage confrontation. Of course, to a certain extent specialization of production and exchange are universal. What is of interest to the study of societal complexity is the elaboration of such strategies for manipulating environmental and intergroup relationships in a way that cannot be explained in terms of localized resources and shortages or the need to interact peacefully with neighboring peoples. The intensification of such strategies, through specialized production and regular use of exchange networks for interregional distribution, seems invariably to occur with, if not indicate, complex systems of societal organization.

Organization complexity is treated in this paper in terms of differentiation, or segregation of the sociocultural system into specialized subsystems, and centralization, or administrative specialization for control of a differentiated system. Such an approach to organizational variability includes both horizontal and vertical dimensions, the former being variation in the number of specialized subsystems at a particular level of an organizational hierarchy, and the latter referring to the number of administrative levels in the hierarchy. In more traditional terms, horizontal variation can be equated with what is commonly known as the division of labor; vertical specialization implies hierarchical organization of decision-making and implementation of strategies.

Two alternative models of the emergence of centralized systems are tested in my analysis of lithic exchange and production. In one model, specialization and exchange are incorporated as key variables in organizational change, while the second model regards them as epiphenomena.
which result from the process of population nucleation. The first model views productive specialization and exchange as examples of horizontal differentiation best coordinated through centralized management. As an alternative, one can argue that productive specialization is caused by vertical differentiation. 29 Specialized production and trade are accounted for in this model as manifestations of the support mechanisms developed to sustain large, permanent population aggregates. In any event, aggregation increases local demand for subsistence and non-subsistence goods and, given vertical specialization, increases demand for craft products and exotic items for signaling status.

Both models assume that during the first millennium A.C. increased population densities and decreased mobility led to adaptations based on exchange to even out localized shortage and surplus. While direct evidence of distribution of perishable foodstuffs is limited, changes in spatial patterning of intrasite storage in this part of the Southwest suggest a shift from household to community storage around 1000 A.C. 30 Given considerable evidence of trade in non-perishable commodities, including both economically critical goods and luxury items, it is reasonable to postulate that both edible surplus and such "bankable" hard goods as raw materials, pottery, jewelry and other exotic commodities were exchanged during early Puebloan times. Such behavior is evident at certain pithouse villages, particularly those with ceremonial architecture and other indications of intersite integrative functions. 31 My analysis accepts this as given and addresses the question of organizational change during the second millennium A.C. from the adaptive perspective on exchange and specialization outlined above. The difference between the two models compared in the study is that one would expect increased productive specialization and trade to precede nucleation while the other would expect nucleation to precede or occur in conjunction with specialized production and trade.

THE FLAGSTAFF-ANDERSON MESA STUDY AREA

Chavez Pass is a natural gap in a rocky escarpment dividing the forested upland of Anderson Mesa to the south and lowlying grasslands of the Little Colorado desert to the north (Fig. 1). Anderson Mesa is the remnant of an extensive lava flow originating near the base of the San Francisco Peaks, a geologically active volcanic field. The top of Anderson Mesa is a pinyon-juniper woodland at around 2000 m. above sea level. The northern edge of the mesa descends onto steep rocky slopes dissected by vertical canyons draining the uplands NE into the Little Colorado River. Ecological differences between Anderson Mesa and the Little Colorado basin include soil types and their depth, hydrology, elevation, relief, and existing flora and fauna. By around 1100 A.C., the ecotone between the two zones was the focus of occupation by subsistence agriculturalists with a dispersed settlement pattern. 32 Chavez Pass and the Flagstaff region were linked by a continuous band of settlement until after the 13th century when the pattern of aggregation at certain strategic points in the linear settlement cluster began to intensify, coinciding with the abandonment of many areas of previous habitation. The Flagstaff region was completely abandoned soon after 1300 A.C. By 1400 A.C., evidence of human activity is limited to the three largest pueblos in the area--Nuvalwentaqa, Grapevine and Kinnkinic--all located at the northern edge of the Anderson Mesa upland. Even Anderson Mesa was completely abandoned by 1500 A.C.
As is typical of large Southwestern sites, Nuvakwewtaqa has produced an impressive data base to document interregional trade. The evidence includes 60 or more decorated ceramic types from all parts of the Southwest except the Hohokam area of southern Arizona; 

- turquoise from the Cerrillos and Azure sources in New Mexico characterized by neutron activation analysis;
- obsidian from the Flagstaff deposits and a variety of others throughout the Southwest sourced by x-ray fluorescence;
- worked and unworked marine shells from the Pacific Ocean and Gulf of California; and a variety of other exotic raw materials and artifacts. Regarding production, there is extensive evidence of fabrication of flaked and ground stone tools; working of shell, bone and stone into ornaments and tools; use of mineral pigments to paint wooden objects, baskets and other artifacts; modeling of clay figurines; and some evidence of local manufacture of ceramic vessels. In addition, a large number of tools assumed to indicate weaving and leatherworking have been found; spindle whorls, associated with processing cotton, however, are notably rare. Much of the pottery, shell and stone jewelry, including all or most of the turquoise, appear to have been imported as artifacts, while debris from the working of many other exotic materials has been found at the site.

Specialized lithic production and exchange were initially indicated by field observations suggesting a nonhomogeneous distribution of imported materials, including unusual densities of manufacturing debris at a few sites. A preliminary analysis of lithic materials in the Chavez Pass district showed that obsidian was far more abundant at Nuvakwewtaqa than sites recorded on survey, and that the frequency of obsidian increased through time at the main ruin. To explore the character of obsidian exchange and to evaluate the evidence of specialized production and trade of non-ceramic materials, I decided to investigate the distribution of lithic remains in the area between Chavez Pass and the obsidian fields 90 km. to the NM in the vicinity of Flagstaff.

The San Franciscan volcanic field is the most prolific source of obsidian in Arizona. Additional sources, some of high quality volcanic glass, are located to the east in New Mexico. Although there are other minor obsidian sources in Arizona, derivation of the majority of obsidian used prehistorically from one or two of the Flagstaff primary deposits has been demonstrated by x-ray fluorescence and spatial analysis of artifactual obsidian distributions. Government Mountain and Sitgreaves Peak (see Fig. 2), about 8 km. apart, are chemically similar, and for purposes of both trace element characterization and archaeological analysis can be treated as one source area.

In general, obsidian from the San Franciscan deposits predominates in samples of volcanic glass from archaeological sites from Flagstaff about 175 km. east to Pinedale, Arizona, although the interface between Flagstaff and New Mexico obsidian distributions varied through time. Chemical analysis of obsidian samples from Nuvakwewtaqa and additional sites employed in the present study indicate an overwhelming occurrence of Government Mountain-Sitgreaves Peak material, except at the South Pueblo at Nuvakwewtaqa where a significant amount of obsidian was traced to Polvadera Peak in New Mexico about 400 km. east of Chavez Pass. Additional trace element research is needed before
Figure 2. Location of obsidian sources and archaeological sites used in the analysis. Sites are numbered on the map and listed in Table 1.

Table 1. Archaeological sites used in the analysis.

<table>
<thead>
<tr>
<th>Site Number</th>
<th>Site Name</th>
<th>Site Description</th>
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the importance of this alternative source can be assessed quantitatively.

Anderson Mesa is an ideal natural laboratory for the study of obsidian exchange. With the San Franciscan obsidian deposits to the NE, and a linear settlement pattern joining the Flagstaff region with Chavez Pass during the period preceding nucleation, the opportunity to examine the articulation of exchange processes with lithic production during the development of the largest and most complex prehistoric community in the area was recognized.

METHODOLOGY AND DATA

The Flagstaff-Anderson Mesa study area was delimited by consulting both published 44 and unpublished 45 site inventories. Survey coverage is good in most of the area due to a long history of archaeological research by the Museum of Northern Arizona in Flagstaff and systematic inventories by the USDA Forest Service which administers most of the land in the study area. Cultural resource surveys have been conducted in all USGS quadrangles, though some which have been thoroughly surveyed have not produced evidence of permanent habitation. The high elevations at the NW end of the study area provide an example. Lands to the north and west of Flagstaff generally exceed 2500 m. in elevation, while located in proximity to the best obsidian deposits in Arizona, lack of prehistoric agricultural potential is most likely responsible for the absence of permanent habitations in the region. 46

The study area conforms to the linear pattern of prehistoric settlement along the northern edge of Anderson Mesa, and thus may be viewed as a culturally bounded survey universe. 47 At the same time, the study area comprises a transect between Chavez Pass and the obsidian sources in the San Franciscan volcanic field. Interpretive problems commonly associated with spatial analyses that use two-dimensional methods to analyze exchange patterns, 48 therefore, do not apply. Exchange in this case may be examined along a single linear axis between the obsidian deposits and settlements increasingly distant from the natural source.

The Sample of Sites

Only permanent habitation sites were employed in the analysis. Sites dating as early as 1100 A.C. were included since I wished to examine patterns of lithic exchange and production during both the period of initial aggregation and the time of nucleation. The time span considered is convenient since the pithouse-pueblo transition in the study area occurred during the 11th and early 12th centuries A.C. Thus, consideration was focused on sites at which relatively obvious masonry remains had been recorded by previous surveys. Large sites were intentionally chosen because existing data showed these to be likely centers of interregional trade. 49 Small sites were also selected and an attempt made to maximize spatial coverage of sites of varying size in the study area. In quadrangles with numerous pueblos of similar size, random selection was used to limit the sample.
Based on these criteria a sample of 31 sites was selected (Fig. 2, Table 1). While the sample is not statistically random, I feel it is representative of permanent habitation sites in the study area dating 1100-1450 A.D. Sites in the sample range from two room structures up to enormous communities such as Nuvakwewtaqa and exemplify architectural diversity in the study area during the relevant time span.

The Artifact Samples

Sites were intensively surface collected using a stratified random sampling design. Although excavated materials are available from some sites included in the analysis, only surface collections were used so that data employed would be comparable. Concern with surface-subsurface variability is obviated through consistent use of surface materials as primary data for an appropriate research problem. In this case, measuring intersite variability in class frequencies such as raw material and artifact types. Rather than estimate the parameters of subsurface artifact populations, variability among surface populations is monitored directly and assumed to reflect intersite differences of prehistoric significance. The main problem with intersite comparisons is therefore potential variation in the degree of previous nonrandom removal of artifacts from the site surface.

All sites in the sample have apparently been subjected to pot-hunting, an inescapable fact in even remote parts of the Southwest. Previous studies of biases introduced through agencies such as casual surface collecting have been considered in conjunction with field observations to evaluate the possibility of such factors influencing intersite differences. For example, the extent of looting is considerably greater at larger sites in the area, but the initial artifact population associated with such pueblos also is greater and thus able to sustain more nonrandom removal of artifacts without seriously distorting samples of surface material. Biases such as obsidian preference are assumed to be relatively constant across sites. One archaeologist who visited many sites in the sample during the 1960s picked up all obsidian he observed, but given the limited size of his obsidian collections the impact was significant only at sites which I found to display extremely high obsidian densities.

My strategy for surface collecting sites of varying size was to balance the fraction and size of the sample so that collections from all sites are comparable. Larger sample fractions were taken on small sites because the probability of sampled class frequencies being representative is less with smaller populations. With the exception of Nuvakwewtaqa, sample fractions range from 4-22% of the area of primary artifact dispersal at each site. Nuvakwewtaqa had previously been surface collected using a slightly different sampling design. Because of the huge size of the site only 1% was collected, but the sample is more tightly stratified and involves a much larger sample size than other sites used in the analysis. In addition, the collect-
tion from Nuvakwewtaqa includes a 1 m x 30 m transect in extramural midden deposits at each of the main pueblos. Since the artifact populations at each of the three is considerably greater than even the next largest site, the samples from Nuvakwewtaqa are regarded as comparable with the others.

Chronology

Chronological control in the Southwest is heavily dependent on typological analysis of tree-ring dated ceramic materials. The technique used to assign dates to assemblages included in this study is based on a mean ceramic date formula in which the frequency of ceramic types and the median date obtained from the references cited above were used to compute both a mean date and standard deviation for a sample of pottery. Absolute dates computed in this way are listed in Table 1 for each site. While the accuracy of such dates is questionable, they were used solely to divide the 31 sites into two broad temporal groups. The first, dating roughly 1100-1250 A.D., corresponds to the period of initial population aggregation. The second period, ca. 1250-1450 A.D., is one of nucleation marking the culmination of this trend, coinciding with the abandonment of most sites in the area. Only six sites fall in the latter period despite efforts to include in the sample all pueblos with evidence of prehistoric occupation after 1250 A.D.

Chronometric data are available for some of the sites. This information was used in making decisions about temporal assignments, such as Pollock 1 with a borderline ceramic date, but both tree-ring dates and several ceramic types indicating that this part of the Pollock site was occupied after 1250 A.D. The ceramic data were employed as the main criterion for chronological assignment since the pottery was recovered in the same context as the lithic samples used in the analysis.

Recent studies suggest the traditional reliance on ceramic typologies for dating may be flawed by socially determined ceramic distributions which also influence intersite variation in ceramic assemblages. The problem is that pottery types which require greater production costs tend to occur with greater abundance on large and important sites in some parts of the Southwest. Thus, the traditional identification of the Pueblo IV time period in terms of polychrome pottery and large pueblos, and earlier periods by smaller pueblos and technologically simple black-on-white ceramic types, may have glossed over significant atemporal variation in areas where the majority of pottery was imported rather than locally made.

Complex patterns of ceramic variability undoubtedly exist in the study area. At Elden Pueblo, for instance, the type site for Harold S. Colton's "Elden focus," stratigraphic evidence shows occupation well into the 13th century A.D., the time range suggested by Colton for the subsequent "Turkey Hill focus." The type site for the latter focus—Turkey Hill Pueblo, known here as Turkey Hills 1—has a mean ceramic date that is no different than Elden Pueblo (cf. Table 1). Thus, while ceramic complexes at the two sites were regarded by Colton as sufficiently different to warrant designation of temporally distinct archaeological units, both ceramic and stratigraphic cross-dating sug-
gest the assemblages are coeval. Interestingly, "Turkey Hill focus" is not evident at sites other than the type site, though it has been suggested at a few multicomponent sites. Intraregional ceramic variability associated with this horizon could be more parsimoniously explained in terms of patterns of differential exchange and/or production. At best, "Turkey Hill" can be seen as a transition between "Elden" and "Clear Creek". Viewing the transition as a discrete entity has masked its true nature—a remarkable period of organizational change—and has given it a deceptive appearance as a gradual and continuous change.

In sum, patterns of ceramic variability which have traditionally been interpreted in terms of stylistic and technological evolution may also reflect complex variation in production, exchange and intraregional distribution of material culture. This argument is supported by chronological data from sites in the study area. The validity of "Turkey Hill focus" as a temporal unit is called into question. For convenience I have retained Colton's terminology and refer to the earlier and later site groupings in my analysis as "Elden" and "Clear Creek" respectively, but caution against a more general acceptance of this unconventional usage. The study area is clearly in need of chronology-building, but this is not the place to propose a revision of Colton's "Sinagua" taxonomy.

Lithic Analysis

Intensive surface collection of the 31 sites selected for study resulted in a probabilistic sample of 4,676 lithic artifacts. A small portion of the sample was classified as ground or pecked stone, but 98% of the lithics are flaked. Each artifact was classified using a morphological typology to discriminate between basic tool and debitage forms on the basis of technological and formal variation. In addition, a detailed attribute analysis was used to code information on raw material type, patterns of edge damage, technology, morphology, and a series of metric attributes. The use-wear analysis employed what has been termed the "low-power approach", using a binocular microscope capable of magnification up to 40X. Description and interpretation of patterns of edge damage followed guidelines set forth by proponents of the method.

The data generated by the lithic analysis were computerized and manipulated using appropriate statistical programs. Computer-assisted comparisons of morphological types with relevant technological, formal and functional attributes were used to group lithics into a more generalized technofunctional classification. The data set which resulted from this procedure is presented in Table 2. The criteria derived for definition of technofunctional types are summarized in Table 3.

Raw Material Source Analysis

Examination of lithic artifacts in the Flagstaff-Anderson Mesa sample included the coding of detailed raw material descriptions. The system was used in conjunction with a comparative collection derived from geological and archaeological sources. Since the primary aim of the raw material analysis was to assign artifacts to geologic proveniences, attention was focused on observation of mineralogical proper-
Table 2. Technofunctional classification of lithic artifacts based on criteria listed in Table 3. Counts in parentheses indicate the number of flaked stone artifacts with evidence of utilization.

<table>
<thead>
<tr>
<th>Counts</th>
<th>Evidence of Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>No evidence</td>
</tr>
<tr>
<td>2.</td>
<td>One evidence</td>
</tr>
<tr>
<td>3.</td>
<td>Two or more evidence</td>
</tr>
</tbody>
</table>

Table 3. Technofunctional type definitions for classification of lithic artifacts in Table 2.

1. **Technofunctional Type Definition:** Centre where the whole dorsal side of the flake and the ventral side have one or more positive concrescent fractures.
2. **Technofunctional Type Definition:** Centre where the whole dorsal side of the flake and the ventral side have two or more positive concrescent fractures.
3. **Technofunctional Type Definition:** Centre where the whole dorsal side of the flake and the ventral side have two or more positive concrescent fractures.
4. **Technofunctional Type Definition:** Centre where the whole dorsal side of the flake and the ventral side have one or more positive concrescent fractures.
5. **Technofunctional Type Definition:** Centre where the whole dorsal side of the flake and the ventral side have one or more positive concrescent fractures.
6. **Technofunctional Type Definition:** Centre where the whole dorsal side of the flake and the ventral side have one or more positive concrescent fractures.
7. **Technofunctional Type Definition:** Centre where the whole dorsal side of the flake and the ventral side have one or more positive concrescent fractures.
8. **Technofunctional Type Definition:** Centre where the whole dorsal side of the flake and the ventral side have one or more positive concrescent fractures.
9. **Technofunctional Type Definition:** Centre where the whole dorsal side of the flake and the ventral side have one or more positive concrescent fractures.
10. **Technofunctional Type Definition:** Centre where the whole dorsal side of the flake and the ventral side have one or more positive concrescent fractures.
11. **Technofunctional Type Definition:** Centre where the whole dorsal side of the flake and the ventral side have one or more positive concrescent fractures.
12. **Technofunctional Type Definition:** Centre where the whole dorsal side of the flake and the ventral side have one or more positive concrescent fractures.
ties, inclusions, color, translucency, transparency and fracture characteristics. Many specimens were examined under a 40X binocular microscope, but most could be classified on the basis of macroscopic criteria.

Laboratory observation resulted in definitions of 151 descriptive raw material types. The descriptions were grouped into more meaningful geologic types using qualitative criteria acquired through published descriptions of source materials and exposure in the lab to the range of macroscopic variation in raw material types. Source assessments were facilitated by geologic survey and literature search, in addition to countless discussions with geologists and archaeologists familiar with northern and central Arizona. Wherever possible, geologic sources were visited and samples collected. The common materials could be confidently assigned to geologic source areas. Low frequency materials were grouped into general indeterminate classes for later interpretive analyses.

Raw material classes were characterized as local or nonlocal. Three regions were defined for this purpose: Flagstaff, Anderson Pass and Chavez Pass. Nonlocal materials were defined in the analysis as those which are thought to occur naturally over 15 km away from the nearest site in the region. The distinctions between regions reflect broad distributional patterns in the surface geology of the study area based on field observation and the study of geologic maps for Arizona in general and Coconino County in particular. In addition, the three regions encompass separate Elden phase site clusters and correspond to locations where nucleated systems emerged during the 13th century.

While most volcanic glass in the San Franciscan volcanic field contains phenocrysts and flow lines, Government Mountain obsidian is generally homogeneous, though less vitreous than many North American obsidians. Macroscopic discrimination of Government Mountain obsidian appears to be fairly reliable. Most commonly, it is slightly translucent with a grey cast, sometimes occurring as greyish bands in a generally black matrix, and occasionally with a thin layer of bright red near the cortex. The nearly opaque coloration is due to the inclusion of numerous grey microcrystalline structures (belonites) ranging to red near the weathered exterior of some pieces. The crystallites do not affect fracture, however; Government Mountain obsidian is isotropic.

Obsidian which fits the description of Government Mountain accounts for at least 94% of the 1163 pieces of volcanic glass in the Flagstaff-Anderson Mesa lithic sample. Similarly, 178 or 190 obsidian artifacts from the study area subjected to x-ray fluorescence as part of a pilot study at the University of California, Berkeley, were characterized as Government Mountain. These results are corroborated by additional trace element research which includes a more detailed chemical characterization of San Franciscoan obsidians, as well as additional x-ray fluorescence and petrographic analysis of obsidian artifacts from Flagstaff, Anderson Mesa and Chavez Pass. In brief, most obsidian in the Flagstaff-Anderson Mesa sample was derived from the Government Mountain-Sitgreaves Peak source area; all is nonlocal material with respect to its archaeological proven-
Results of the raw material source analysis were tabulated both by counting the number of specimens within each class and by summing their weights. Both variables provide measures of raw material frequency, but with slightly different behavioral referents. Variation in the aggregate weight of raw materials is in many respects preferable for monitoring exchange since it more exactly reflects the volume of material flow through an exchange system. However, weight is also more likely to reflect variability caused by opportunistic use of bulky materials which may be unevenly distributed on the landscape. For instance, sites located on volcanic bedrock in the Flagstaff region frequently have a few large core tools of very coarse basalt which cannot be worked into formal tool types. Nevertheless, on some sites it occurs literally underfoot and provides suitable raw material for fabrication of "instant tools." Such artifacts constitute a major portion of the aggregate weight of the lithic assemblage at some sites, yet clearly are minor components of the local technology. In contrast, lithic debitage counts, while more relevant technologically, can over-represent raw material frequencies when the variable of interest is raw material flow. Pressure flaking, for example, results in many small pieces of waste; in some cases such variation in the intensity of manufacturing activity is more critical than the mass of raw material left at the site.

In sum, count and weight both are significant variables in a study concerned with exchange and production. The former provides an index of independent technological acts, while the latter more closely moni-
Table 4. Flaked stone raw materials by count and by weight (in grams) for the Chavez Pass region.

<table>
<thead>
<tr>
<th>LOCAL MATERIALS</th>
<th>NON-LOCAL MATERIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>KAERAD CHEMT</td>
<td>ANDIKE CHEMT</td>
</tr>
<tr>
<td>CHAVEZ PASS 1</td>
<td>357.2</td>
</tr>
<tr>
<td>CHAVEZ PASS 2</td>
<td>1082.3</td>
</tr>
<tr>
<td>CHAVEZ PASS 3</td>
<td>1084.0</td>
</tr>
<tr>
<td>CHAVEZ PASS 4</td>
<td>232.0</td>
</tr>
<tr>
<td>CHAVEZ PASS 5</td>
<td>327.0</td>
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<tr>
<td>CHAVEZ PASS 6</td>
<td>91.1</td>
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<tr>
<td>CHAVEZ DRAW 2</td>
<td>240.0</td>
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<tr>
<td>CHAVEZ DRAW 3</td>
<td>507.0</td>
</tr>
<tr>
<td>CHAVEZ MTH. 1</td>
<td>47.9</td>
</tr>
<tr>
<td>CHAVEZ MTH. 2</td>
<td>61.7</td>
</tr>
<tr>
<td>CHAVEZ MTH. 3</td>
<td>60.3</td>
</tr>
<tr>
<td>TOTAL NUMBER PERCENT</td>
<td>44.8</td>
</tr>
<tr>
<td>TOTAL WEIGHT PERCENT</td>
<td>39.8</td>
</tr>
</tbody>
</table>

Table 5. Flaked stone raw materials by count and by weight (in grams) for the Anderson Pass region.

<table>
<thead>
<tr>
<th>LOCAL MATERIALS</th>
<th>NON-LOCAL MATERIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>KAERAD CHEMT</td>
<td>ANDIKE CHEMT</td>
</tr>
<tr>
<td>DIABLO 1</td>
<td>257.8</td>
</tr>
<tr>
<td>POLLOCK 1</td>
<td>37.2</td>
</tr>
<tr>
<td>POLLOCK 2</td>
<td>160.7</td>
</tr>
<tr>
<td>POLLOCK 3</td>
<td>230.7</td>
</tr>
<tr>
<td>POMMELIN ECK</td>
<td>195.8</td>
</tr>
<tr>
<td>GRAPEVINE</td>
<td>256.2</td>
</tr>
<tr>
<td>ANDERSON PASS 1</td>
<td>43.2</td>
</tr>
<tr>
<td>ANDERSON PASS 2</td>
<td>162.3</td>
</tr>
<tr>
<td>PIGEON CANYON</td>
<td>370.3</td>
</tr>
<tr>
<td>TOTAL NUMBER PERCENT</td>
<td>18.3</td>
</tr>
<tr>
<td>TOTAL WEIGHT PERCENT</td>
<td>28.1</td>
</tr>
</tbody>
</table>
LITHIC PROCUREMENT ON ANDERSON MESA

Statistical techniques are employed in this part of the paper to manipulate data derived from the raw material source analysis. The geologic distribution of lithic resources is briefly described, followed by a short discussion of regional patterns of raw materials acquisition and use, and, finally, the archaeological distribution of obsidian is examined for evidence of prehistoric interaction. The spatial analysis of artifactual obsidian employs fall-off models to explore the effects distance from source has on the frequency of obsidian at sites in the study area.

The objectives of the spatial analysis are twofold. First, lithic exchange networks are modeled. The hypothesis that lithic exchange was homogeneous and unspecialized is tested and rejected in favor of a hierarchical model of differentiated exchange in which obsidian was traded between central places within the exchange network. The second objective of the spatial analysis is to generate expectations for testing in the second phase of the study—an examination of technofunctional variability. Based on results of the fall-off analysis, the exchange model characterizes sites either as procurement centers or recipient sites for comparison with evidence of lithic production.

Natural Distribution of Lithic Resources

The geology of Anderson Mesa has never been studied systematically. The entire landform is basaltic, representing a Quaternary extrusion overlying sedimentary bedrock of Permian to Triassic age. Anderson Mesa basalt ranges in texture from coarse-grained to vesicular, and is commonly quartzitic, a characteristic not known to occur among other...
basalts found in northern Arizona. The rock has an irregular fracture; it is infrequently flaked, but occurs commonly as grinding and hammerstones on Anderson Mesa.

Volcanism associated with the San Francisco Peaks, the ruins of a composite volcano, has attracted the attention of geologists and archaeologists alike. The San Franciscan volcanic field consists of a complex array of cinder cones, plugs, dikes, domes and various flows, and includes a diversity of andesitic and rhyolitic rocks. Most basalt in the area is extremely coarse or vesicular; it was utilized for pecked and ground stone artifacts and was occasionally flaked to make tools where it was readily available. Fine-grained to vitreous basalt also exists in localized sources. Nine primary obsidian sources have been described in the volcanic field, while intensive but localized exploitation of additional minor outcrops and secondary sources is apparent archaeologically.

In addition to the Quaternary igneous complex which characterizes the Flagstaff-Anderson Mesa study area, four marine sedimentary formations are exposed at various localities. The uppermost formation, known as the Chinle, exists south of the Little Colorado River only as isolated erosional remnants, but is widespread north of the Little Colorado. Chinle is a mudstone and siltstone formation containing petrified wood and other fossils, as well as sedimentary chert and chert conglomerate. It is best known at Petrified Forest where Triassic plants have been silicified with many whole trees replaced by colorful jasper, chert, chalcedony and quartz. In the study area Chinle caps only a single long ridge south of Anderson Pass, but also occurs on two buttes known as the Sunset Mesas NE of Chavez Pass. The only chert from the Chinle formation which is common at archaeological sites to the south of the Little Colorado is a brittle, isotropic variety grading from milky white to reddish-brown, generally with yellow, blue or grey mottling. This material has been referred to as Chinle chert and I will retain that term.

Beneath the Chinle formation is the Moenkopi which outcrops along the entire northern edge of Anderson Mesa. Moenkopi consists of horizontally-bedded reddish-brown shale grading into sandstone, occasionally found as artifactual ground stone. It was more commonly used prehistorically for architectural purposes. In addition, weathered deposits of Moenkopi shale appear to have been major clay sources for ceramic manufacture on Anderson Mesa.

The formation which appears most extensively in the study area is Kaibab Limestone, a fossiliferous chert-bearing stratum underlying the Moenkopi. It is exposed on or near the ground surface of most of the land north of Anderson Mesa and occurs in a number of canyons which cut through the basalt-capped mesa system. A distinctive opaque chert occurs as beds and nodules in the limestone. It has a matte finish with color ranging from white to tan, pink or grey. The chert is unusually hard and is not easily flaked using soft hammer or pressure tools. Such chert is widespread in northern Arizona where Kaibab is the dominant bedrock. Kaibab contains additional varieties of chert, including silicified sponges used as knapping material. Because of the extreme diversity of these cherts, and limited sampling of the extensive geologic deposits in which they are found, they were combined and referred to as Kaibab chert.
Coconino Sandstone lies under the Kaibab formation and is exposed in the study area only near Flagstaff at Walnut Canyon. The formation consists of sandstone and dolomite and contains no cryptocrystalline quartz. The sandstone is too soft to make functional milling stones, but was used as architectural stone in locations where it is readily available.

Finally, in addition to in situ chert sources in the Kaibab and Chinle formations, the colluvial slopes of Anderson Mesa contain secondary deposits of quartzite and chert pebbles. Since the geomorphic association is not alluvial, the presence of these waterworn pebbles suggests the decomposition of a gravel deposit. The most likely derivation is the conglomerate of the Chinle formation (Shinarump member) which has been completely eroded from nearly all of the study area. Many varieties of chert were traced to the Anderson Mesa colluvium: in this paper I refer to them collectively as Anderson Mesa chert.

Regional Patterns of Raw Material Use

Many interesting patterns in the prehistoric exploitation of lithic resources are revealed by partitioning the Flagstaff-Anderson Mesa sample into regions. Even a casual inspection of Tables 4, 5 and 6 demonstrates great interregional variation in the frequency of obsidian. The percentage at Anderson Pass is well over twice as great as at Flagstaff, half the distance from Government Mountain. Even the Chavez Pass district, nearly 100 km. from the source, seems to have nearly as much obsidian as Flagstaff, though by count it is less frequent. The discrepancy between relative obsidian frequencies measured by count versus weight in all three of the regions, compared to the other raw materials, indicates that obsidian lithics generally are smaller than those of other material types. The utility of measures based on both count and weight is evidenced by this variability.

Despite the relative scarcity of obsidian in the Flagstaff region the majority of flaked stone still is volcanic in origin (Table 6). Basalt, which was available on demand in the Flagstaff region, is the predominant volcanic material. Most is quite coarse and cannot be construed as an easily procured substitute for obsidian since the two are not equivalent. With the exception of obsidian, volcanic and metamorphic rocks are better represented by weight than by count; most artifacts in the latter two categories are quite large and crude, only rarely with retouch. Obsidian occurs throughout the study area mainly as small debitage and retouched tools.

Chert was used much more extensively on Anderson Mesa than in the Flagstaff region. The proportionate scarcity of basalt is not attributable to its geologic distribution since Anderson Mesa is itself basaltic. The local basalt was used frequently for ground stone, not represented in the raw material tables, but was flaked on only a few "hones" and other large bifaces not in the probabilistic samples. Artifactual basalt found on Anderson Mesa is more commonly fine-grained, a characteristic not observed in the local basalts.

Most of the chert found archaeologically in the Chavez Pass district was obtained from the Kaibab formation. This material makes up over 60% of the total raw material sample (Table 4). It is locally available at both primary outcrops and as transported pebbles in alluvial...
visi) and colluvial deposits. A statistically significant association between high frequencies of Kalbab chert and sites located on Kalbab bedrock has been demonstrated by previous research, which also revealed a proportionate increase in Chinle chert at sites not situated on or near limestone. Thus, the inhabitants of sites at which Kalbab chert was not readily available opted for importing Chinle chert, a highly isotropic and brittle stone, rather than local chert frequently flawed by limestone and fossil inclusions.

Although outcrops of Chinle chert have not been located near Anderson Mesa, the slopes of a long ridge extending NE from Anderson Pass are composed of Chinle bedrock. I have quarried Chinle chert on the Little Colorado in an analogous geologic context, and regard Anderson Pass as a probable source of Chinle chert in the Anderson Mesa area. The abundance of Chinle chert at sites near Anderson Pass suggests it was more easily obtained than elsewhere in the study area (Table 5), though the greater quantity of obsidian in the Anderson Pass region demonstrates ready access to nonlocal material through some form of exchange. The greater variety of lithic materials in the Anderson Pass sample also suggests trade; the majority of lithics classified in the tables as miscellaneous cherts are known to be nonlocal. Of the Anderson Pass sites, only Padre Canyon is situated on Kalbab bedrock, and this is the only site in the region with a majority of the sample composed of Kalbab chert.

In sum, the majority of stone used as knapping material by prehistoric inhabitants of the Flagstaff-Anderson Mesa study area was easily obtained at or near the pueblo. Outcrops of Kalbab chert and basalt are abundant in the Chavez Pass and Flagstaff regions respectively. The geologic situation at Anderson Pass is diverse, with Kalbab and probably Chinle chert in localized deposits. While the location of outcrops was most likely well known prehistorically, the exploitation of some lithic resources was probably quite incidental. The unconcentrated secondary deposits of quartzite and Anderson Mesa chert are more amenable to acquisition through what Lewis Binford has termed “embedded procurement.” Such a strategy of raw materials acquisition is “embedded” in the subsistence-settlement system such that useful resources not easily obtained through intensive procurement are simply collected when encountered during daily activities. The low yet consistent frequencies of quartzite and Anderson Mesa chert support such a model of casual exploitation. Clearly, however, there must be a “demand” threshold beyond which an embedded procurement strategy, though efficient, is simply inadequate. Thus, exploitation of the primary outcrops and secondary deposits may represent alternative strategies of raw materials acquisition.

A third strategy of raw materials acquisition is interregional exchange. Certainly trade is also commonly “embedded,” as in local procurement, though in this case the matrix is social. The acquisition of obsidian in sizable quantities as at some of the sites in the study area, however, suggests purposive exchange. There are no permanent habitation sites near Government Mountain which may have controlled access to obsidian. Numerous concentrations of obsidian debitage have been recorded in the vicinity of Government Mountain, suggesting that primary reduction of bulk occurred at temporary camps and/or workshops.
near the major obsidian deposits.

The frequency of nonlocal lithic materials is greatest in the Anderson Pass region where about half of the sample is nonlocal, compared to roughly one-fourth at Chavez Pass and considerably less than one-fourth at Flagstaff. Interestingly, Anderson Pass is the only region where high quality knapping material appears to be locally available. Obviously, the procurement of nonlocal lithic resources entailed factors in addition to the availability of suitable local materials.

Introduction to the Regression Analysis

Recent advances in the archaeological study of trade have been facilitated by the development of both accurate methods to source raw materials and quantitative models for describing interaction at the regional level. Fall-off models have proven especially productive for the quantitative description of prehistoric exchange patterns. In conjunction with linear regression analysis, fall-off models treat exchange as a response variable, related inversely to the effective distance between sites at which trade items occur and the natural source or production center from which the commodity originated. The essentials of this methodology are fully explicated in the literature cited above. Only a few aspects of modeling and interpreting distance-decay functions need be discussed in the present context.

Fall-off models have been employed in a number of studies which use exchange patterns to monitor aspects of prehistoric social organization. While some applications of this approach have been criticized for simplistic attempts to link particular fall-off models with idealized types of social organization, fall-off curves are effective for measuring certain organizational characteristics of exchange networks. Of particular importance to the present research is the characteristic of centralization. Centralized artifact distributions can result from at least two factors, the first being the obvious concentration of a commodity near its source. Centralization, however, may also result from differential supply of commodities due to what Colin Renfrew has termed "directional trade". As he notes, central places within an exchange network may reflect either functional specialization or differential access to particular resources. Directional trade of some decorated ceramic wares has been demonstrated in the Plateau Southwest and explained in terms of status-restricted access to certain imported items. In an exchange system characterized by neither preferential access nor economic specialization, distance-decay functions are expected to show a gradual, monotonic decrease.

Archaeological evidence that centralization within an exchange network is due to socially determined patterns of access to nonlocal resources can be used to indicate societal complexity of the kind commonly subsumed by the labels chiefdom and state. Functional centralization, however, implies neither status nor centralized decision-making, but simply some degree of economic specialization. Factors as diverse as geographic location or political administration of production may influence such specialization. Concentrations of trade items do not necessarily prove centralization of the sociocultural system, though centralized exchange functions reflected by recurring
concentrations of diverse commodities at the same locus are not to be expected in non-centralized societies.\textsuperscript{101}

The development of central places in an exchange network prior to the appearance of centralized settlement systems would support the model of specialization of exchange as a cause of nucleation. Alternatively, the absence of centralized exchange during the period of initial aggregation would indicate that this kind of specialization is unlikely to explain the emergence of centralized communities during the subsequent period. As a preliminary test of the two models, evidence of centralized obsidian exchange will be examined in this section. In the following section, results are compared with evidence of manufacturing activity to assess the influence of functional specialization. Finally, the data are contrasted with other central place functions to determine whether centralized exchange was tied to centralization of the sociocultural system.

The null hypothesis in testing both of the alternative models is that obsidian was exchanged through down-the-line trade between neighboring villages or through a simpler form of exchange such as direct access. Centralized artifact distributions in non-centralized societies should be attributable to a decline in the effective distance between sites and the source of the trade goods,\textsuperscript{102} functional differentiation,\textsuperscript{103} or anomalous rates of artifact discard.\textsuperscript{104} I do not regard the latter as likely to profoundly affect raw material frequencies in samples composed mainly of debitage, though differential discard might be a critical factor in the distribution of tools per se.

The geography of the Flagstaff-Anderson Mesa study area permits the assumption that linear distance and the "effective distance" assumed to monitor relative costs of obsidian transport are nearly equivalent. Anderson Mesa forms a natural corridor between Chavez Pass and the San Francisco obsidian sources without significant barriers impeding pedestrian travel. Government Mountain is recognized as the major point of origin for obsidian in the study area. The effect of alternate sources on the distance-decay data is assumed to be negligible due to the clustering of other obsidian deposits in proximity to Government Mountain (cf. Fig. 1). Only the O'Leary Peak-Robinson Crater source area is closer to the Flagstaff archaeological sites. While this obsidian was exploited locally, x-ray fluorescence has failed to identify it in archaeological samples from sites in the fall-off analysis.

Given these conditions, the fall-off pattern predicted by the down-the-line model takes the form of an exponential distance-decay function.\textsuperscript{105} Additional functions have been defined for describing other patterns of unstructured, homogeneous exchange\textsuperscript{106} or to integrate "supply zone" effects in which sites surrounding the source receive the good in large quantities irrespective of varying distance.\textsuperscript{107} Modeling down-the-line trade on the edge of an extended supply zone is possible using a power function referred to as the Pareto model.\textsuperscript{108} A situation in which all sites interact directly with the source is approximated by a linear function.\textsuperscript{109} A great deal of entrepreneurial behavior, however, if not most economic transactions, are embedded in a more complex sociocultural network.\textsuperscript{110} The long-term effects on the archaeological record are essentially random. Such activity has been modeled as "random walk" behavior, in which case the Gaussian model of
fall-off is appropriate.\textsuperscript{111}

Despite this diversity of fall-off models, each describes a monotonic pattern of attenuation as a function of source-to-site distance. Relatively complex distance-decay curves have been shown to result from directional trade, geographic barriers, supply zones, and recently\textsuperscript{112} interaction between competing exchange networks. Only directional trade, however, has been shown to create centralized patterns of spatial variation not associated with the commodity's origin.

The following analysis compares relative frequencies of obsidian for the sites in each phase with four theoretical models of fall-off: Linear, Exponential, Pareto and Gaussian. Where appropriate, regressions were facilitated by logarithmic and exponential transformations of the variables—distance and obsidian frequency—as prescribed by the references cited. The regression analysis then was extended to include concentration effects in an effort to improve the poor fit of non-hierarchical models.

Obsidian Procurement: 1100 to 1250 A.C.

The relationship between distance to Government Mountain and the relative frequency of obsidian in each of the Elden phase lithic assemblages, computed from counts, is illustrated in Figure 3. While the relationship is generally inverse, there are several significant departures from the overall trend. This variability is even more pronounced in the plot of obsidian frequency measured by weight (Fig. 4), suggesting that sites with unusually high obsidian frequencies also tend to have larger sized obsidian artifacts.
To test the hypothesis that obsidian was exchanged through a down-the-line system or simpler mode of exchange, the four fall-off models discussed above were fitted to obsidian frequencies for each site using data for both counts and weight (Table 7). Similar results were obtained for all of the models and for both measures of obsidian frequency. However, the fit of the models in each case is poor, with all correlation coefficients (r) under 0.5. The best fit is the Linear Model, which accounts for approximately one-fourth of the variance. Examination of Figures 3 and 4 indicates that these statistics demonstrate no more than the fact that a linear function is best able to average a significant amount of variability.

An alternative to the models of homogeneous exchange is that obsidian was traded between central places. To test this hypothesis, I first plotted separate exponential curves for the Flagstaff and Anderson Pass regions (Fig. 5). The range of spatial variation in the Chavez Pass sample is insufficient to plot a third regional curve, but the pattern displayed is similar to that of the other two regions with a centralized distribution apparent in each of the three. When the hypothesized "sources" are compared with an exponential curve depicting down-the-line exchange between regional centers, a fairly good fit is obtained (Fig. 6). These results support the tentative identification of six regional procurement centers: Elden Pueblo and Turkey Hills 1 in the Flagstaff region; Chavez Pass 5 and Chavez Draw 2 in the Chavez Pass district; and Anderson Pass 1 and 2, located on Anderson Mesa about midway between Flagstaff and Chavez Pass (Fig. 2).

The evidence of intraregional centralization was further examined by fitting each of the four theoretical fall-off models to the data from
Table 7. Fall-off models fitted to obsidian frequencies for all Elden phase sites combined.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>EQUATION</th>
<th>Y</th>
<th>M</th>
<th>B</th>
<th>R</th>
<th>R²</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>( Y = MX + B )</td>
<td>Count</td>
<td>23.09536</td>
<td>-.20563</td>
<td>-.49862</td>
<td>.24862</td>
<td>.01070</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>6.23323</td>
<td>-.05768</td>
<td>-.48012</td>
<td>.23051</td>
<td>.01381</td>
</tr>
<tr>
<td>Pareto</td>
<td>( Y = MX^{-B} )</td>
<td>Count</td>
<td>7.74583</td>
<td>-1.48968</td>
<td>-.47823</td>
<td>.22871</td>
<td>.01416</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>7.31929</td>
<td>-1.74463</td>
<td>-.43574</td>
<td>.18987</td>
<td>.02416</td>
</tr>
<tr>
<td>Exponential</td>
<td>( Y = ME^{-BX} )</td>
<td>Count</td>
<td>3.12765</td>
<td>-.02299</td>
<td>-.46313</td>
<td>.21449</td>
<td>.03250</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>1.92242</td>
<td>-.02709</td>
<td>-.42452</td>
<td>.18022</td>
<td>.02755</td>
</tr>
<tr>
<td>Gaussian</td>
<td>( Y = ME^{-BX^2} )</td>
<td>Count</td>
<td>2.41193</td>
<td>-.00076</td>
<td>-.44842</td>
<td>.20108</td>
<td>.02074</td>
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<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>1.09797</td>
<td>-.00020</td>
<td>-.41803</td>
<td>.17475</td>
<td>.02966</td>
</tr>
</tbody>
</table>

Definition of terms:

- X = Distance to Government Mountain
- Y = Obsidian Frequency (Percent)
- M = Intercept of the Least-Squares Regression Curve
- B = Slope of the Least-Squares Regression Curve
- E = Base of the Natural Logarithm

Figure 5. Obsidian fall-off by count compared with intraregional exponential curves for the Flagstaff and Anderson Pass regions.
Flagstaff and Anderson Pass separately. Source-to-site distances were re-measured in the Anderson Pass region, assuming that Anderson Pass 1, where the most obsidian was recovered, had served as the major source of obsidian in the region. Regression statistics computed for each of the models (Tables 8 and 9) indicate a much better fit than obtained prior to partitioning the data set into separate regions (compare Table 7). Unlike the earlier regressions, higher correlations were invariably achieved with relative frequencies computed from weights.

Results for the Flagstaff sample are somewhat ambiguous (see Table 8). On the basis of counts, the best fit is the Linear Model, but on the basis of weight the statistics are lowest for this model. Since for all four models the fit is much closer with frequencies computed by weight, these data would appear to be more reliable than counts, as suggested by theoretical consideration of exchange flows discussed earlier. The Pareto Model is able to account for the greatest amount of variance in relative weights, though statistics are similar for the Exponential Model. Both would indicate down-the-line trade, though the Pareto suggests that the site nearest the source—Elden Pueblo, where the greatest frequency was found—constitutes the edge of a supply zone. Given the absence of contemporaneous sites nearer the source, this interpretation is reasonable. Since the correlation is only moderate, however, the down-the-line model is in any event not able to fully explain the distributional pattern.

Correlation coefficients are considerably higher with the Anderson Pass data (Table 9). Both count and weight frequencies produce the best fit with the Linear Model. For all of the models, however, stronger correlations are provided by weight. Both the Linear and
Table 8. Fall-off models fitted to obsidian frequencies for Elden phase sites in the Flagstaff region.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>EQUATION</th>
<th>Y</th>
<th>M</th>
<th>B</th>
<th>R</th>
<th>$R^2$</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>$Y = MX + B$</td>
<td>Count</td>
<td>63.67694</td>
<td>-1.19086</td>
<td>-1.19086</td>
<td>.64445</td>
<td>.41532</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>19.02436</td>
<td>- .39243</td>
<td>- .39243</td>
<td>.75993</td>
<td>.57734</td>
</tr>
<tr>
<td>Pareto</td>
<td>$Y = MX - B$</td>
<td>Count</td>
<td>16.17340</td>
<td>-3.77835</td>
<td>-3.77835</td>
<td>-.54398</td>
<td>.29592</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>22.56225</td>
<td>-6.98667</td>
<td>-6.98667</td>
<td>-.88655</td>
<td>.78597</td>
</tr>
<tr>
<td>Exponential</td>
<td>$Y = e^{-BX}$</td>
<td>Count</td>
<td>5.67268</td>
<td>-.08500</td>
<td>-.08500</td>
<td>.51972</td>
<td>.27011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>7.37265</td>
<td>-16.261</td>
<td>-16.261</td>
<td>.87628</td>
<td>.76787</td>
</tr>
<tr>
<td>Gaussian</td>
<td>$Y = e^{-BX^2}$</td>
<td>Count</td>
<td>3.79759</td>
<td>-.00093</td>
<td>-.00093</td>
<td>.49417</td>
<td>.24421</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>3.89910</td>
<td>-.00185</td>
<td>-.00185</td>
<td>.86255</td>
<td>.74399</td>
</tr>
</tbody>
</table>

Definition of terms: See Table 7

Table 9. Fall-off models fitted to obsidian frequencies for Elden phase sites in the Anderson Pass region.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>EQUATION</th>
<th>Y</th>
<th>M</th>
<th>B</th>
<th>R</th>
<th>$R^2$</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>$Y = MX + B$</td>
<td>Count</td>
<td>108.70007</td>
<td>-1.23862</td>
<td>-1.23862</td>
<td>.92730</td>
<td>.85988</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>44.01658</td>
<td>-.50796</td>
<td>-.50796</td>
<td>.93195</td>
<td>.86854</td>
</tr>
<tr>
<td>Pareto</td>
<td>$Y = MX - B$</td>
<td>Count</td>
<td>62.25359</td>
<td>-14.49348</td>
<td>-14.49348</td>
<td>.86551</td>
<td>.74910</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>100.57216</td>
<td>-22.83448</td>
<td>-22.83448</td>
<td>.91057</td>
<td>.82913</td>
</tr>
<tr>
<td>Exponential</td>
<td>$Y = e^{-BX}$</td>
<td>Count</td>
<td>16.12588</td>
<td>-.17938</td>
<td>-.17938</td>
<td>.86341</td>
<td>.74548</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>23.43247</td>
<td>-.28579</td>
<td>-.28579</td>
<td>.91856</td>
<td>.84376</td>
</tr>
<tr>
<td>Gaussian</td>
<td>$Y = e^{-BX^2}$</td>
<td>Count</td>
<td>8.87818</td>
<td>-.00110</td>
<td>-.00110</td>
<td>.86039</td>
<td>.74026</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>12.02291</td>
<td>-.00178</td>
<td>-.00178</td>
<td>.92585</td>
<td>.85720</td>
</tr>
</tbody>
</table>

Definition of terms: See Table 7
Gaussian models yield similar results, in each case accounting for over 85% of the variance. The Linear Model would suggest villages in the Anderson Pass region acquired obsidian directly from Anderson Pass 1, while the Gaussian implies more diffuse interaction. Since the distance involved is no more than 15 km., both processes appear to be probable. However, the Linear Model is a stronger measure of centralization because distribution of obsidian would entail direct interaction with the hypothesized first-order center in the exchange network.

Figure 7 shows obsidian frequency by weight plotted on a logarithmic scale. The distance-decay function should be transformed to a straight line if fall-off is exponential. Instead, intraregional centralization is accentuated; Anderson Pass forms a peak about halfway between Flagstaff and Chavez Pass. The relationship between the hypothesized centers and lower-order sites in each region is approximately linear, supporting the argument developed earlier that intraregional exchange was homogeneous. The overall pattern, however, is rather convex.

In summary, the analysis of obsidian procurement supports a model of hierarchically organized directional trade. Interregional exchange evidently involved direct linkage between regional centers. Intraregional exchange can be characterized as a down-the-line system in the Flagstaff region, and somewhat more centralized at Anderson Pass. The null hypothesis of interregional exchange through a down-the-line network of neighboring sites is rejected. In addition, I am able to argue that obsidian exchange in the area was organized at the regional level...
during the Elden phase, though intraregional distribution may have been quite informal.

Obsidian Procurement: 1250 to 1450 A.C.

The applicability of regression analysis and fall-off modeling to the study of exchange is limited after 1250 A.C. because of a dramatic decrease in the number of sites during the period of nucleation. Distance-decay data computed on the basis of lithic counts are presented in Figure 8. The plot shows such tremendous variability that curve-fitting attempts on the basis of six sites would seem rather meaningless. The relative frequency of obsidian measured by weight is about three times less, but the same pattern of intersite variation is evident (Fig. 9). Though regression statistics are probably not needed to demonstrate the significance of this variation, Table 10 is presented to show the complete lack of statistical support for the hypothesis that obsidian frequencies and source-to-site distances are in any way correlated for sites of this period.

Obsidian is relatively scarce at Old Caves Ruin, nearest the source and only 12 km. south of O’Leary Peak-Robinson Crater. In contrast, two sites in the Anderson Pass region—Kinnikinick and Grapevine, both having dense concentrations of lithic debris—have assemblages in which obsidian constitutes around 60% of the count data and 20% of the aggregate weight. Of particular interest is the relative paucity of obsidian at the Pollock site, only a few km. from Kinnikinick and Grapevine. While the latest occupation of this locus, referred to here as Pollock
Figure 9. Obsidian fall-off by weight for Clear Creek phase sites.

Table 10. Fall-off models fitted to obsidian frequencies for Clear Creek phase sites.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>EQUATION</th>
<th>Y</th>
<th>M</th>
<th>B</th>
<th>R</th>
<th>R²</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>( Y = MX + B )</td>
<td>Count</td>
<td>23.98663</td>
<td>.03249</td>
<td>.03017</td>
<td>.0091</td>
<td>.47738</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>5.10017</td>
<td>.04416</td>
<td>.09202</td>
<td>.00847</td>
<td>.43118</td>
</tr>
<tr>
<td>Pareto</td>
<td>( Y = MX^{-B} )</td>
<td>Count</td>
<td>3.3266</td>
<td>-.10423</td>
<td>-.03676</td>
<td>.00135</td>
<td>.47244</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>.07431</td>
<td>.23836</td>
<td>.04759</td>
<td>.00226</td>
<td>.46434</td>
</tr>
<tr>
<td>Exponential</td>
<td>( Y = Me^{-BX} )</td>
<td>Count</td>
<td>3.29310</td>
<td>-.00529</td>
<td>-.11048</td>
<td>.01221</td>
<td>.41748</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>1.01602</td>
<td>.00109</td>
<td>.01287</td>
<td>.00017</td>
<td>.49035</td>
</tr>
<tr>
<td>Gaussian</td>
<td>( Y = Me^{-BX^2} )</td>
<td>Count</td>
<td>3.33820</td>
<td>-.00007</td>
<td>-.19247</td>
<td>.03705</td>
<td>.35743</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight</td>
<td>1.20954</td>
<td>-.00002</td>
<td>-.02624</td>
<td>.00069</td>
<td>.48032</td>
</tr>
</tbody>
</table>

**Definition of terms:** See Table 7
1, probably ended during the 14th century, there appears to be a long period of overlap with Kinnikinick and some overlap with Grapevine (cf. Table 1). Variation in obsidian frequency among the three sites therefore reflects extreme spatial variability and/or change in the volume of obsidian trade. The Elden phase evidence of centralized obsidian procurement at Anderson Pass, compared with the very low incidence of obsidian at nearby Pollock 2 and 3 (see Table 5), suggests that much of this variability is attributable to intraregional differentiation. Nevertheless, comparing Elden and Clear Creek phase data shows that temporal variation is also significant. According to ceramic evidence, the Anderson Pass centers were certainly abandoned by the 13th century, about the time that the main occupation of Kinnikinick began. Also apparent in the fall-off plots is a significant difference between the two southern roomblocks at Nuvakwewtaqa. Chavez Pass 1, the largest of all sites in the area, has four times more obsidian than Chavez Pass 2, the SE pueblo at Nuvakwewtaqa. Thus, spatial and temporal variability in obsidian use both appear to be great.

Transportation constraints measured by procurement distance cannot account for intersite variation in obsidian frequency. Given the lack of evidence of permanent habitation in the Flagstaff region during most of the Clear Creek phase, the enormous quantities of obsidian at Kinnikinick and Grapevine were-most likely obtained through direct acquisition from the geologic source. Interestingly, sourced obsidian samples from these two sites are all of Government Mountain-Sitgreaves Peak variety, suggesting greater specialization of procurement than at other sites where samples have been subjected to trace element analysis.

THE ORGANIZATION OF LITHIC PRODUCTION

Most lithic exchange studies are characterized by failure to identify the kind of relationship that linked raw materials acquisition and artifact manufacture. Exchange models lacking such information are simplistic and potentially inaccurate. Instead of assuming isomorphism between distribution and production processes, lithic technofunctional variability is examined in the following section through statistical tests designed to yield information independent of that produced by the fall-off analysis. My purpose at this point is to compare the technological organization reflected by lithic assemblages at sites identified tentatively as obsidian procurement centers with other contemporaneous sites. Before turning to intersite technofunctional variability, some commonalities in the organization of lithic production and use must be discussed.

Puebloan Lithic Technology: Preliminary Considerations

The typological approach to stone tools which Southwestern archaeologists have traditionally embraced directs attention to a subset of tools that is only a portion of most Puebloan lithic assemblages. Knives, scrapers and projectile points are generally identified as typical stone tools, yet the few assemblages examined in detail show that technologically simple implements, many without retouch, are at least as common as more easily recognized formal tool
types. Of the 401 lithics in the Flagstaff-Anderson Mesa sample that display edge damage indicative of use-wear, 60% lack retouch entirely. The majority of these are nondescript flakes, but shatter and cores account for 20% of the unretouched lithic implements. The remainder, comprising half of the total number of lithics with use-wear, are simply utilized flakes.

The number of utilized edges identified per implement is presented in Table II. In the sample of utilized lithics, 57% show use-wear on only a single edge. Tools were not used intensively. Pieces of unretouched debitage, for instance, generally have several potentially usable edges. Use-wear is present on just one edge, however, on 66% of the unretouched implements. A similar pattern of lithic utilization was described at the Joint site in eastern Arizona by Michael Schiffer. The mean number of utilized edges per implement, employed by Schiffer as a use-intensity index, is 1.20 for shatter and flakes compared with 1.47 for the Flagstaff-Anderson Mesa sample. Reworking and resharpening of tools was observed only rarely in the sample of lithics, even on formal tools. The edge of the striking platform was routinely inspected for use-wear sustained prior to resharpening of a tool edge. Only a few of the thousands of flakes analyzed appear to be byproducts of this kind of tool maintenance. Morphological evidence of hafting occurs only on 13 of the artifacts in the probabilistic sample: 26.5% of the formal tools.

In sum, the investment in stone tool manufacture is generally minimal, a widespread characteristic of the ceramic period in the Southwest. In Lewis Binford's terminology, the major component of

<table>
<thead>
<tr>
<th>NUMBER OF UTILIZED EDGES</th>
<th>Flake</th>
<th>Shatter</th>
<th>Shatter</th>
<th>Core-Primary</th>
<th>Core-Secondary</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13</td>
<td>21</td>
<td>22</td>
<td>16</td>
<td>13</td>
<td>96</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>6</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>TOTAL</td>
<td>196</td>
<td>22</td>
<td>143</td>
<td>400</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Puebloan lithic technology can be described as expediently manufactured situational gear. As such, low rates of curatlon can be expected, a prediction supported by the use-wear analysis. Amplified by the evidence of raw materials acquisition discussed in the previous section, a pattern of casual exploitation of lithic resources is clear. In the context of such an informal and expedient lithic technology, the organized procurement and distribution of obsidian through regional centers is of particular interest. Information on specific uses of obsidian in the local lithic technologies is essential to understanding the obsidian trade.

Table 12 presents data on raw material modification. Raw materials were grouped qualitatively into categories ranked by fineness of the material. Both functional and technological modifications are compared with raw material classes using a Chi-square test of independence. While the null hypothesis of no association between raw material and technofunctional modification is rejected at the .001 level, the contingency coefficient (Cramer's V) shows the relationship between variables is low, suggesting additional factors influencing raw material selection. Clearly, however, obsidian was used preferentially for bifacial reduction, especially fabrication of projectile points. The brittle and isotropic properties of volcanic glass provide an ideal medium for refined knapping with soft hammer and pressure tools. Though obsidian constitutes less than one-third of the lithics that were retouched and/or utilized, 70% of the projectile points are made of obsidian. The percentage of each raw material category that was retouched bifacially decreases consistently from one-third of the
obsidian to 6% of the igneous and metamorphic materials.

When utilized without retouch, obsidian tends to show only functional modification, indicating the sharpness of freshly fractured obsidian, with an edge thickness approaching molecular proportions, was perceived as a useful attribute. Granular materials such as Tselab chert and especially the igneous and metamorphic materials show a tendency toward utilization in the form of informal tools with limited retouch, in most cases minimal trimming of a single edge. In the study area, it would appear that exchange of obsidian, the only raw material extensively traded between regions, was primarily a reflection of its superior for technological modification through fine retouch. Utilization of obsidian debitage and informal tools was probably a secondary use. Two lines of evidence are offered to support this model of raw material use. The evidence will be used to reject a purely functional hypothesis of obsidian utilization in which the distribution of obsidian is attributed to varying site-specific demands for cutting implements, rather than to provide raw material for production of formal tools.

Experimental research with Government Mountain obsidian has shown that core reduction aimed entirely at production of flake blanks for projectile point manufacture results in quantities of waste similar in size and shape to the utilized debitage in archaeological collections from the Flagstaff-Anderson Mesa study area. Utilized obsidian artifacts in the prehistoric sample rarely include unbroken core reduction flakes over 3 cm in length or other pieces which could have been used as projectile point blanks. The quantity of debitage produced during experimental core reduction that would have been adequate in the local industries only for use as informal implements is slightly greater than the total number of flake blanks produced during core reduction. This finding rather closely approximates the ratio of informal implements to formally retouched tools for the obsidian sample in Table 12. The use of obsidian as unretouched debitage and minimally retouched pieces can therefore be tentatively interpreted as lateral cycling of manufacturing debris.

The second test of the functional hypothesis was based on archaeological data. In devising the test, Schiffer’s use-intensity index was modified to measure the extent of functional utilization to which an entire assemblage had been subjected. As presented originally, the use-intensity index measures the mean number of utilized edges per implement to gauge the intensity of tool use in a sample of utilized lithics. More relevant to the problem at hand is a measure of the degree to which an entire lithic assemblage has been modified by tool-using behavior. This measure, the Assemblage Use-Intensity Index (AUI), is defined as the total number of utilized edges divided by the number of lithics, utilized or unutilized, in an assemblage. Large values reflect intensive utilization of the assemblage, while low values indicate less utilization and proportionately more tool manufacturing activity.

Since the functional hypothesis identifies the naturally sharp edge of obsidian debitage as the critical factor in obsidian selectivity, unretouched flakes and shatter would be utilized most intensively if the hypothesis has merit (cf. Table 12). Sites having three or less
pieces of obsidian were deleted from the analysis since they may be unrepresentative. The AUI was computed for the remaining 17 sites and compared using the Asen-Walsh test, a difference of means test that does not require sample sizes or population variances to be equal.

The mean AUI for Elden phase sites identified by the fall-off analysis as obsidian procurement centers is 0.14930 (s=0.05485; n=6), while the value for other Elden phase sites is 0.45238 (s=0.27982; n=6). The null hypothesis of no difference between means can be rejected (t'=-2.38401; A.R.> |t'|>2.12837; alpha=.05). On the average, obsidian was utilized three times more intensively at the hypothesized recipient sites than at procurement centers. Conversely, utilization is less evident at the latter sites, suggesting greater emphasis on knapping obsidian than the use of informal obsidian tools. For all raw materials combined, the mean AUI for early sites is 0.094170 (s=0.083400; n=25). While the obsidian AUI for the hypothesized procurement centers falls into this range, obsidian at the other sites was used much more efficiently (t'=-2.38387; A.R.> |t'|>2.12432; alpha=.05). Thus, while relatively inefficient use of obsidian at procurement centers might simply reflect an abundance of raw material, the abundance is not due to greater demands for sharp-edged cutting implements.

Similar comparisons were used to assess functional differences between Kinlarkinick and Grapevine, on the one hand, where the relative frequency of obsidian is the greatest, and the other four Clear Creek phase pueblos. The mean AUI at the latter four sites is 0.13012 (s=.15617; n=4), while at Kinlarkinick and Grapevine the figure is 0.08881 (s=.05982; n=2). The null hypothesis in this case is overwhelmingly supported (t'=-4.65111; R.R.> |t'|>2.25169; alpha=.05). While obsidian was generally used somewhat less intensively at Kinlarkinick and Grapevine, variance among the other four pueblos is great. The AUI is especially low at Chavez Pass I where the value is 0.08000, suggesting—as does the large amount of obsidian recovered there—the possibility of lithic specialization despite the fact that relative frequencies at Nuvakwetqua were suppressed on the fall-off plots by the abundance of obsidian at Kinlarkinick and Grapevine, which have at least three times more obsidian than any other site. For all raw materials, the mean AUI for Clear Creek phase sites is 0.06825 (s=.02425; n=6), slightly lower than for obsidian, though both site types conform to the range.

The foregoing analyses indicate that informal tools were generally used less intensively during the Clear Creek phase than previously. The difference between the two periods is not statistically significant, however. There is a slight increase through time in the incidence of retouched tools, which comprise 39.9% of the utilized lithics on the earlier sites, but 46.2% of the Clear Creek collection (cf. Table 12). Thus, there is some evidence for a temporal trend toward more use of retouched tools and less intensive utilization of unretouched debitage. The assemblages from Elden phase obsidian procurement centers provide a precedent for this trend.

To summarize, I have argued that the local lithic resource base was supplemented through the exchange of obsidian primarily because of
selectivity on the part of stoneworkers involved in making bifacial tools. An alternative hypothesis was tested to determine whether differential demands for obsidian to carry out tasks using informal cutting tools might account for intersite variation in the frequency of obsidian. In rejecting this hypothesis the argument that obsidian was imported mainly as raw material for bifacial knapping was strengthened. In the following section, the articulation of lithic production and obsidian exchange is examined more closely.

Lithic Specialization: A Technological Approach

Intersite comparisons with the Assemblage Use-Intensity Index show that differential use of informal tools cannot account for the Anderson Mesa obsidian trade. A stronger case can be made for a negative correlation between the use of informal obsidian implements and spatial and temporal variation in the intensity of obsidian acquisition. The centralized procurement of volcanic glass appears to reflect a demand for superior raw material to fabricate bifacial tools. My objective in this section is to relate organizational characteristics of lithic production to the exchange network described earlier in the article.

If the primary use of obsidian in the study area was to provide raw material for manufacturing bifacial tools, we may expect sites with unusual quantities of obsidian—those identified as procurement centers in the fall-off analysis—to be "break of bulk" centers with large quantities of decortication and core reduction waste. Though not mutually exclusive, the two hypotheses can be separately tested through technological comparisons of ostensible procurement centers with contemporaneous sites. Two stages in the lithic reduction process will be analyzed: biface manufacture and core reduction.

The archaeological evidence of obsidian core reduction technology consists mainly of shatter and flakes. Obsidian cores are uncommon, even in excavated samples from Huvakwewtaqa, suggesting their scarcity is not simply a function of nonrandom surface collecting by previous visitors. Obsidian cores generally are less than 10 g. in weight and were commonly retouched and utilized as tools. In my experience with Government Mountain obsidian, I was normally able to produce flake blanks even after reducing the core to 4-5 cm. in length. Beyond that, it was generally possible to retouch the core into a biface for use as a blank, leaving no "core" for the archaeological record. The scarcity of obsidian cores in the study area, even where core reduction is indicated by large decortication flakes, suggests that efficiency such as that I achieved was common among prehistoric obsidian knappers. Because of this, however, cores are not reliable indicators of obsidian core reduction activity.

Of particular importance to understanding the obsidian trade are the remains of preliminary stages of core reduction. Such material is diagnostic of break-of-bulk centers where raw materials are processed
for subsequent transport and use. If obsidian procurement centers were nodes in the exchange network but not specialized manufacturing centers, wastage from break-of-bulk operations should be prevalent. However, if procurement centers also functioned as manufacturing loci, bifacial reduction debitage would be expected (cf. Table 12). Both hypotheses are compatible with the differentiated pattern of tool-use intensity discussed in the previous section. While the former would indicate a primary exchange function for the procurement centers, the latter, in addition, would demonstrate centralization of production activities.

The break-of-bulk hypothesis was tested with evidence of obsidian decortication. The initial results were somewhat surprising (Table 13). The relative frequency of cortex on obsidian shatter and flakes is consistently greater at sites thought to have been recipients of the obsidian trade. The implication that samples from the procurement centers include more tertiary flakes indicates that a break-of-bulk function is untenable. However, since bifacial reduction flakes are generally quite small and unusually thin, a second test was conducted with debitage greater than 2 mm in thickness. Table 13 shows the disparity between procurement centers and other sites in the same region is less for the larger debitage. Clearly, however, cores were flaked at both site types.

The relatively low incidence of cortical waste suggests a certain reduction of bulk before obsidian was introduced to the sites in the sample. The most likely candidates for such preliminary knapping are limited activity sites near Government Mountain. The frequency of cortex in even the Chavez Pass district, nearly 100 km away from the

<table>
<thead>
<tr>
<th>Table 13. Percent cortex for obsidian shatter and flakes.</th>
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<tbody>
<tr>
<td>REGION</td>
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<tr>
<td>Chavez Pass</td>
</tr>
<tr>
<td>Procurement Center</td>
</tr>
<tr>
<td>Recipient Sites</td>
</tr>
<tr>
<td>Anderson Pass</td>
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<tr>
<td>Procurement Centers</td>
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</tr>
<tr>
<td>Procurement Centers</td>
</tr>
<tr>
<td>Recipient Sites</td>
</tr>
</tbody>
</table>

* Sample of debitage over 2 mm. thick includes only three pieces from Pollock 1.
source, indicates that cores were the most common form of obsidian exchanged between regions. The somewhat equivocal contrast between Elden phase procurement centers and recipient sites suggests—in addition to more refined knapping at the centers—that intraregional distribution also involved cores.

While anomalies in the relative frequency of obsidian could be identified in the fall-off analysis, simple comparisons between the hypothesized procurement centers and recipient sites mask a certain amount of intersite variability. Although there are only six Clear Creek sites to compare, a fairly definite pattern of specialization is evident. Obsidian is present in huge quantities at both Grapevine and Kinnikinick. In the sample of obsidian debitage over 2 mm thick, 20.0% of the Kinnikinick material displays cortex, while this figure is only 10.9% at Grapevine and 12.1% at Nuvakwewtaq. Since the sample is large for these sites (n=275), the statistics are reliable, unlike Pollock 1 which has only three pieces of obsidian over 2 mm in thickness. Kinnikinick would appear to have been a primary node in the obsidian trade.

Given the low frequency of obsidian and obsidian cortex at Old Caves Ruin, it is likely that residents of Kinnikinick obtained obsidian directly from Government Mountain. It is highly improbable that a Clear Creek phase site large enough to have systematically supplied Kinnikinick and Grapevine with the tons of obsidian estimated to exist in the extensive subsurface deposits at the two sites remains to be found in the Flagstaff region. Probably several additional metric tons of obsidian were passed on to Nuvakwewtaq. In addition to intensive knapping of obsidian, a great deal of labor must be postulated to account for acquisition and transportation of volcanic glass on Anderson Mesa during the 14th and 15th centuries.

While regional centralization of obsidian procurement has been demonstrated, evidence of centralized processing has been offered for only the Clear Creek phase system. During the Elden phase, obsidian cores were most likely traded between regional centers and distributed within regions through relatively informal systems of "down-the-line" and/or "random walk" exchange. Although regional procurement centers apparently did not preform nodules for subsequent trade, an emphasis on certain manufacturing activities has been suggested by two lines of evidence. First, the unusually high densities of obsidian at these sites cannot be explained in terms of a break-of-bulk effect. The procurement centers have more tertiary flakes and the recipient sites have a greater percentage of decortication debris. Second, the demand for obsidian cutting implements appears to be greater at recipient sites. Procurement sites have proportionately more unutilized debitage which appears to be tool manufacturing debris. A third line of evidence will now be presented to test the hypothesis that obsidian procurement centers were specialized loci of biface production.

The rationale for the biface production hypothesis is based on evidence of preferential use of obsidian as raw material to make projectile points and other pressure flaked bifaces (cf. Table 12). If lithic production were specialized, it is probable that such specialization was articulated with the obsidian trade. It follows that obsidian procurement should vary to the extent that production of formal bifacial
tools was stressed at particular sites. If specialized production of bifaces involved subsequent exchange of the artifacts produced, utilized bifaces might vary independently of debitage from bifacial knapping.

The bifacial production hypothesis is intended as a plausible link between lithic production and the obsidian trade. Although the association of bifaces and obsidian has been demonstrated, bifacial tools were manufactured prehistorically from other raw materials (see Table 12). Because my objective is to relate a system of lithic reduction (biface manufacture) and a system of raw materials exchange (the obsidian trade), a broader perspective on lithic technology is appropriate. The analysis which follows is therefore concerned with obsidian, as well as the variety of alternative raw materials used in producing flaked stone artifacts.

Adducing archaeological evidence of bifacial reduction is quite tractable in some lithic industries. The knapping of large bifaces, for example, creates not only distinctive flakes of bifacial retouch, but also diagnostic patterns in lithic debitage assemblages. However, the lithic technology relevant to this paper is one characterized by very small arrow points, many less than 2 cm in length. The projectile points were made mainly by pressure flaking, generally with little or no bifacial thinning. Soft hammer flakes of bifacial retouch are uncommon at sites in the study area.

Replicative experiments under controlled conditions of debitage retrieval were undertaken to assist in devising test implications for the bifacial production hypothesis. It was discovered that numerous projectile points could be replicated, yielding very little debris which might be recovered in the field using one-quarter inch hardware cloth. Other than quantities of core reduction waste from manufacturing flake blanks, the most numerous remains from my knapping activities were broken preforms and fragments resulting from bifacial reduction errors and error recovery. Given the limited potential of debitage analysis for reconstruction of small point reduction, the test of the bifacial production hypothesis employed frequencies of tools rather than debitage.

Assemblages of flaked stone tools were divided into three categories for testing the bifacial production hypothesis: (1) expedient tools—unifacially or bifacially retouched pieces with evidence of functional utilization; (2) formal tools—utilized bifaces and projectile points; and (3) tool blanks—retouched lithics with no sign of utilization, most of them originally classified on the basis of morphological criteria as preforms. While the last category was expected to characterize manufacturing loci, the former should be more abundant at other sites. If the bifacial production hypothesis is supported, formal tools should vary across site types if the products of lithic specialization were widely exchanged, and be predominant at obsidian procurement centers if linked to a system of differential tool use. Hammerstones were also included in the hypothesis test. Investigations of the local lithic technology suggest these were utilized as percursors in most core reduction activity and for retouching of informal tools. The frequency of hammerstones and relative intensity of bifacial reduction activities should thus vary inversely. The use of soft hammer flaking and pressure retouch for bifacial reduction are indicated by
flake scar morphology on bifaces in the sample, as well as by antler and bone tool kits excavated in association with bifaces at Nuvakwewseaq.

Chi-square tests were used to assess the degree of relationship between varying tool frequencies at the hypothesized manufacturing loci compared to sites where obsidian was less frequent. The biface production hypothesis is strongly supported for the Elden phase sample (Table 14). The null hypothesis of no relationship between site types and tool types can be rejected at the .001 level, while the correlation coefficient indicates the relationship is moderate. All of the differences between observed and expected tool frequencies are in the direction predicted by the biface production hypothesis. There is a greater proportion of bifacial tools at manufacturing centers, suggesting that finished bifaces were not distributed along with obsidian cores or that bifaces were frequently broken, aborted or lost during the manufacturing process. The latter possibility is supported by the prevalence of laterally snapped specimens; the sample includes only one projectile point with an impacted tip indicative of utilization (cf. Table 2).

Although a statistically significant relationship can also be shown for the Clear Creek phase data, the strength of association is weaker (Table 15). Hard hammer flaking is again better represented at the hypothesized nonspecialized sites, though bifacial retouch is also apparent. The trend is the same as with Elden phase sites, satisfying the predictions of the biface production hypothesis. Interestingly, deviation between observed and expected frequencies is least among formal tools, possibly due to exchange of finished artifacts. Additional factors

<table>
<thead>
<tr>
<th>SITE TYPE</th>
<th>EXCEPENT Tools</th>
<th>HAMMER N</th>
<th>TOTAL</th>
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<tr>
<td>Procurement Centers</td>
<td>20</td>
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<td>58</td>
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<td>14.8</td>
<td>27.1</td>
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<tr>
<td>Expected</td>
<td>14</td>
<td></td>
<td></td>
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<tr>
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<td>44</td>
<td>36.9</td>
<td>80.9</td>
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<tr>
<td>Observed</td>
<td>7</td>
<td>11.5</td>
<td>18.5</td>
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<tr>
<td>Expected</td>
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</table>

<table>
<thead>
<tr>
<th>TOTAL</th>
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<th>20</th>
<th>18</th>
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<tbody>
<tr>
<td>TOTAL</td>
<td>137</td>
<td>35</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 14. Chi-square test for differences in tool frequencies at Elden phase sites.

Cramer’s V = .36506

$X^2 = 18.25736$

$df = 3$

$p < .001$
responsible for the weaker correlation coefficient may include inter-sit variability not expressed by the dichotomous characterization of the large Clear Creek phase pueblos as either specialized manufacturing loci or recipient sites.

RESULTS AND CONCLUSIONS

Spatial and technofunctional analyses of lithic remains have been used in this paper to model prehistoric exchange and production within and between regions in the Flagstaff-Anderson Mesa study area. Three forms of lithic raw materials acquisition were identified. Adequate raw material for making expedient tools was obtained locally through quarrying of in situ chert and basalt, supplemented by "embedded procurement" of redeposited quartzite and chert. In addition, a variety of nonlocal materials were utilized, particularly on Anderson Mesa. Only obsidian, however, was systematically imported in large quantities. The intensity of obsidian procurement was such that a network of inter-regional trade was proposed to account for its distribution.

Centralization of the obsidian trade by the 12th century A.D. is evident in the study area. Procurement centers were identified in each region and shown to be linked to a moderately specialized bifacial industry supplied with obsidian and other raw materials. Procurement centers in the Flagstaff region were situated as close to obsidian deposits as agricultural commitments would allow. They apparently distributed volcanic glass to neighboring sites, while interacting directly with regional center(s) at Anderson Pass, an artery in communication between Flagstaff and Chavez Pass. Anderson Pass also provides
an easy route between the Little Colorado valley and Mogollon Rim country via the Canyon Diablo drainage. Thus, the exceptionally strong pattern of centralized obsidian exchange and production at Anderson Pass during the Elden phase may have been partly fortuitous.

Obsidian trade was far more intensive during the Clear Creek phase. Exchange and production were heavily centralized. The specific role of particular villages in the obsidian exchange network varied significantly. Direct procurement of Government Mountain obsidian is evident at Kinnikinick Pueblo, as are break-of-bulk activities in the plazas surrounding the village. Tons of obsidian were worked at the site and additional tons of obsidian cores passed on to Grapevine and Nuvakwewtaqa. The variety of archaeological remains suggesting a port-of-trade function at Chavez Pass suggests that vast quantities of obsidian and/or obsidian artifacts may also have been traded beyond the limits of the study area. Chemical characterization of obsidian from Clear Creek phase contexts at Nuvakwewtaqa indicates interregional exchange, though Kinnikinick and Grapevine specialized in procurement and reduction of Government Mountain obsidian.

Although the relative frequency of obsidian at Nuvakwewtaqa does not warrant identification as a specialized obsidian procurement center, the greater frequency of obsidian at Chavez Pass 1 suggests some centralization in the local settlement system, as well as intrasite specialization. Such a finding is not a surprise for a community of such scale. The greatest concentration of obsidian at the site occurs in the large central plaza of Chavez Pass 1. The density of obsidian excavated in association with the burned roof of the great kiva on the west edge of the plaza is sufficient to warrant the term "workshop" and to postulate centralized acquisition and distribution of obsidian at Nuvakwewtaqa. Recovery of an adult male interment associated with debitage and stone tools in various stages of production provides evidence of part-time craft specialization at Nuvakwewtaqa, as well as for reconstructing the production trajectory of a stylized projectile point type characteristic of the area. A similar burial was excavated at Elden Pueblo in the Flagstaff region, also inferred with abundant lithic remains and antler knapping tools.

The intensity of industrial activity at Chavez Pass 1, Kinnikinick and Grapevine provides an interesting contrast with the Pollock site. Residents of Pollock, located just over 1 km from Kinnikinick, did very little obsidian knapping, though several obsidian projectile points were found at the site. The best explanation, if armed conflict is ruled out, is one of craft specialization and exchange rather than status-restricted access to obsidian. The intensively terraced agricultural fields directly associated with the Pollock site suggest productive specialization of a different kind than that evident at Kinnikinick and Grapevine.

An association of obsidian concentrations and bifacial tool manufacturing also was demonstrated for Elden phase sites. The unexplained variance in the regional fall-off analyses may reflect the influence of factors such as status on intraregional obsidian distribution. A major anomaly in the pattern of down-the-line trade in the Flagstaff region, for example, is the difference between the two pueblos investigated at New Caves Ruin. The relative frequency of obsidian at New
Caves 1, directly associated with a plaza and great kiva complex, is 10.9% by count, though the frequency by weight is quite low. The large sample of lithics from New Caves 2, however, contains no obsidian. As with Huyakwewata, this intrasite distribution suggests centralized procurement and trade, perhaps characterized by preferential access within the community.

Regression analysis of obsidian distributions in an egalitarian setting in SW New Mexico achieved better statistical correlations with models of monotonic fall-off. In the Flagstaff-Anderson Mesa study, greater variability not accounted for by even the best-fit models of intraregional trade suggests more complex intervillage relationships. The hierarchical exchange network modeled in the present study provides an interesting contrast to the incipient down-the-line system of SW New Mexico. The correspondence between the exchange system described in both articles and the kinds of sociocultural systems reconstructed for the two areas based on independent archaeological evidence recommend distance-decay modeling as a viable and adaptable method for exploring organizational aspects of prehistoric exchange.

Explaining Organizational Change

A hierarchical network of interregional exchange has been described in this paper. The level of specialization characteristic of the 12th century A.C. would not have required centralized intervillage leadership or regional administration of exchange and production activities. The system was influenced considerably by cultural and natural geographic factors. However, systematic interaction between regions and centralized intraregional production and exchange were demonstrated with Elden phase data. Intraregional specialization thus did not evolve as a consequence of nucleation. While obsidian trade centers in the Flagstaff region were large and important villages, procurement and production centers at Chavez and Anderson Pass were located at fairly small sites (cf. Table 1). The density of coeval sites in proximity suggests that they may have been components of more complex multisite communities. However, larger population aggregates existed at the time, for example at Pollock 3 and Chavez Pass 3. While the latter communities appear to have been more centralized organizationally, they were not central places in the flourishing obsidian trade.

Functional specialization in the Elden phase regional systems was probably not managed through centralized decision-making. However, subsequent changes in the location and context of specialized production and trade, as well as intensification of the obsidian trade, suggest nucleation may have developed in part due to more effective manipulation of intraregional diversity and specialization by influential individuals located at growing population centers, whether to personal advantage or that of the community at large.

Administration of interregional exchange and production during the Clear Creek phase is suggested by other archaeological evidence. While Elden phase plainware ceramics in the Chavez and Anderson Pass regions are technologically distinguishable, during the subsequent Clear Creek phase Kinnikinick and Grapevine in the Anderson Pass region are dominated by Chavez Pass brownwares, yet the local plainware tradition seems to persist at the Pollock site. Excavated tree-ring samples and
decorated ceramic collections from Kinnikinnick and Pollock 1 (Table 1) fail to support chronological inferences that might be drawn from this variation, suggesting instead that the sites are contemporaneous. Rather than view the extensive Pollock site complex as a nucleated community, ceramic remains are most parsimoniously interpreted, as are the tree-ring dates, to indicate the sort of horizontal stratigraphy revealed by excavations at Chavez Pass 3. Also similar is a site layout that seems to reflect gradual agglomeration and aggregation compared to the pre-planned architectural layout of Kinnikinnick, Grapevine and the South Pueblo at Muvakewtata, sites which were nucleated communities.

At its zenith the Pollock site was probably a relatively minor population center, perhaps dominated by nearby Kinnikinnick, and apparently not favored by interregional trade. Its failure to profit from a growing sphere of panregional social, political and economic interaction may have contributed to its collapse. Kinnikinnick and Grapevine, with a monopoly on the thriving Government Mountain obsidian trade, were occupied as much as a century after the Pollock site was finally abandoned.

The implications of this model of economic growth based on local specialization articulated through intra- and interregional dependencies in explaining the ultimate failure of the "Classic Pueblo" phenomenon are not considered in this paper. However, I have argued that the obsidian trade is an important aspect of economic intensification which characterizes this period of Southwestern prehistory. Evidence that the 14th century economic system was preceded by a complex network of interregional obsidian exchange, including centralized intraregional production and distribution, supports such a view. Specific causal relationships among these and additional organizational variables need to be clarified before the process of nucleation can be explained satisfactorily. Based on the data and analysis I can offer at this time, it would appear that lithic production and trade should be viewed as component variables in the process, and not simply consequences of nucleation on Anderson Mesa.
FOOTNOTES


10. Idem, op. cit. (in note 5) 287, fig. 46; 288, fig. 47.


12. Ibid.


15. Ibid.


18. S. Plog, op. cit. (in note 3).


21. See especially Cordell and Plog, op. cit. (in note 5).

22. F. Plog and Herbs, op. cit. (in note 4) 5-10.


33. Upham, Lightfoot and Feinman, op. cit. (in note 6).

34. Upham, op. cit. (in note 5) 332.


41. Findlow and Bolognese, op. cit. (in note 39).

42. Findlow (see note 35).

43. Ibid; Jack, op. cit. (in note 38).


46. See also Colton, op. cit. (in note 7) 260-266.


49. Fish, Pilles and Fish, op. cit. (in note 44) 171.


52. Wilson, op. cit. (in note 7) 272-274.


54. Lewarch and O'Brien, op. cit. (in note 50) 305.

55. Batcho, op. cit. (in note 7) 3-4.


58. Decorated ceramics were identified by Dr. Steadman Upham and T. Kathleen Henderson using type collections curated by the Department of
I am very grateful for this courtesy. Bryant Bannister, Elizabeth A. H. Gell and John W. Hannah, Tree-Ring Dates from Arizona, Verde-Sho~low-St. Johns Area (University of Arizona Laboratory of Tree-ring Research: Tucson 1966) 22-23, and F. Plog, op. cit. (in note 5) 420-421; Upham and Fef~tan, op. cit. (fn note 6), 61. Upham, op. cit. (fn note 5) 320-332; Upham , Lightfoot and Fef~tan, op. cit. (fn note 6), 62. Peter J. Pilles, Jr., personal communication, 1981. See Colton, op. cit. (fn note 7) 17, Table 1. 64. Pilles (see note 62). 65. The Clear Creek focus was equated by Colton with the Pueblo IV period, which he places between 1300-1400 A.D. in the Flagstaff area. 66. George H. Odell and Petrea Odell-Vereecken, "Verifying the Reliability of Lithic Use-wear Assessments by Blind Tests: The Low-power Approach," JFA 7 (1980) 87-120.


74. Jack, op. cit. (in note 38) 111.

75. Sanders, op. cit. (in note 38).

76. Ibid. 49, Table 12; Findlow (see note 35).

77. See Wilson, op. cit. (in note 7) 274-275.


81. Schreiber and Breed, op. cit. (in note 71) 115-119; Robinson, op. cit. (in note 80) 55, 67.

82. Personal observation, 1981.


84. Moore, Wilson and O'Haire, op. cit. (in note 70).

85. H. Wesley Pierce, personal communication, 1981.

86. Margerie Green, personal communication, 1981.


89. LePere, op. cit. (in note 36) 21-23, Table 1, fig. 3.

90. Moore, Wilson and O'Haire, op. cit. (in note 70).


92. Pilles (see note 62).


96. Renfrew, op. cit. (in note 93) 85.

97. Ibid. 86.

98. Upham, op. cit. (in note 5) 223-278.

99. Renfrew, op. cit. (in note 93) 72, 85.

100. F. Plog, op. cit. (in note 95) 137.


102. Renfrew, op. cit. (in note 93) 72; Hodder, op. cit. (in note 101) 244.

103. Renfrew, op. cit. (in note 93) 85-86; F. Plog, op. cit. (in note 95) 131.


108. Renfrew, op. cit. (in note 93) 74.


110. Ibid 79.

111. Renfrew, op. cit. (in note 93) 75-76, 79-80.

112. Findlow and Bolognese, op. cit. (in note 39).

113. The assumption underlying this procedure is that the majority of sites in the Flagstaff and Anderson Pass regions were supplied by regional "sources" rather than a single geologic source. The exponential distance-decay functions drawn in fig. 5 were computed by averaging the obsidian frequencies for the two sites in each region with the most obsidian, and dividing the frequency in half at regular intervals between sites.

114. Sites lacking obsidian were not included in fig. 7.


116. Jack, op. cit. (in note 38) 112, Table 3; Helene Warren cited in Wilson, op. cit. (in note 7) 276; Findlow (see note 35).


119. For comparison with Schiffer's data, I computed a use-intensity index for all specimens, though a more reliable index can be derived from a constrained sample of complete implements on which all potential working edges can be observed. In the Flagstaff-Anderson Mesa sample the use-intensity index is 1.60 for complete specimens.


123. Ibid, 269, For a somewhat different perspective, compare Schiffer, op. cit. (in note 118) 166-178.


126. Idem, op. cit. (in note 118) 159.

127. Lyman Ott, An Introduction to Statistical Methods and Data Analysis (Wadsworth: Belmont, Ca. 1977) 117.


134. Upham, op. cit. (in note 5) 304-337.


138. Pilles (see note 62).
139. Findlow and Bolognese, op. cit. (in note 93).

140. See also Upham, op. cit. (in note 19); idem, op. cit. (in note 5); Cordell and F. Plog, op. cit. (in note 5).


143. The ceramic collection from the Pollock site lacks Jeddito Yellow Ware, a common 14th and 15th century grave good in the area, but does contain contemporaneous pottery such as Homolovi Polychrome, Chavez Pass Black-on-red, and slightly earlier types such as Kayenta Polychrome, Tutiwha Black-on-orange, and Pinedale and Polacca Black-on-white. Such ceramics seem to be associated with the main roomblock at Pollock, as well as burial areas around the site; in general, Pollock 2 and 3 are characterized by earlier black-on-white pottery, mainly Little Colorado Whitewares.

144. G. Brown, op. cit. (in note 11).