I, April Greenberg, hereby submit this original work as part of the requirements for the degree of Master of Arts in Anthropology.

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A GIS-Based Spatial Analysis of Factors that Influenced the Placement of Fire-Cracked Rock Features in the Upper Basin, Northern Arizona

Student’s name: April Greenberg

This work and its defense approved by:

Committee chair: Alan Sullivan, PhD
Committee member: Susan Allen, PhD
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April R. Greenberg
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Committee: Alan P. Sullivan, III, Ph.D., Chair

Susan E. Allen, Ph.D.
This thesis uses Geographic Information Systems (GIS) to evaluate factors that may account for the spatial pattern of fire-cracked rock (FCR) piles and scatters in the Grand Canyon-Upper Basin region. Prior investigations conducted by the Upper Basin Archaeological Research Project (UBARP) and limited excavation data indicate that FCR features were used by prehispanic groups to process undomesticated plants in bulk quantities. By exploring the spatial distribution of FCR features and their relationship to other types of archaeological phenomena, environmental and cultural factors that may have influenced their placement on the landscape are evaluated. Environmental characteristics such as slope, elevation, aspect, and attributes of terrestrial ecosystem units of Kaibab National Forest exhibit little variation where archaeological phenomena are documented. Therefore, such factors are considered inconsequential in FCR feature location. Behavioral processes that may have influenced FCR feature distribution are examined by identifying their spatial pattern and their relationship to neighboring archaeological remains. I argue that the presence of abandoned features and masonry structures, from which raw materials could be salvaged, influenced the placement of FCR features and structured how particular spaces functioned for later groups. Data generated in this analysis support Upper Basin land-use models and demonstrate the manner in which localized processes such as re-use of abandoned features are expressed in spatial patterns of the region’s archaeological record.
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Chapter 1: Introduction

Introduction to the Problem

In contrast to other areas in the prehispanic Southwest, there is little archaeological evidence in Northern Arizona’s Upper Basin of an agriculturally-based economy. Rather, it seems that horticultural practices and environmental modification strategies were adopted to increase the abundance and availability of undomesticated plant resources (Sullivan 2013). One such strategy entails the deliberate burning of the pinyon-juniper woodland understory in order to increase the diversity and quantity of edible resources (Sullivan 1996). This low-investment modification would allow for planning in accordance with a predictable growth rate and maximizing the carrying capacity of a particular ecological setting by increasing biomass potential. Other technological adaptations employed to optimize wild-resource return include the construction of terraces for small-scale, and perhaps experimental, horticultural enterprises involving wild or domesticated plants, and check-dams and alignments designed to capture and channel water (Sullivan 2000).

Knowledge of the characteristics and seasonality of floral and faunal resources was an important adaptation in prehistoric Southwestern cultures, and is referenced throughout the archaeological and ethnobotanical literature (Cook 1995; Doebley 1984; Floyd and Kohler 1990; Fowler and Rhode 2011; Minnis 1989; Sullivan 1987). Re-use and scavenging of materials from preexisting, abandoned anthropogenic features are economic strategies that are indicated in the archaeological record of the Upper Basin region (Sullivan et al. 2001). Re-purposing raw materials from and re-use of features may reflect the degree to which the landscape, including its archaeology, was known to groups through varying perennial and seasonal sequences of
occupation. Episodes of re-use also are representative of an effective economic approach that reduced planning time and labor expenditure (Bayman and Sullivan 2008). One example of such re-use has been proposed in prior investigations of fire-cracked rock (FCR) features in the Upper Basin, which were used to process wild-plant resources in bulk quantities (Sullivan 1992). The role of FCR piles and associated features, such as roasting pits, in the production of wild-plant resources has been well documented elsewhere in the Southwest region (Cook 1995; Eerkens et al. 2002; Thoms 2009). Prior to documentation by the Upper Basin Archaeological Research Project (UBARP), FCR features had not been recorded at upland elevations, such as those of the Grand Canyon-Upper Basin. Investigations conducted by UBARP regarding the origins of FCR features have revealed that they were initially constructed and used by Grand Canyon Anasazi and Cohonina groups, who inhabited the region perennially, and were re-used over the subsequent 250 years by groups, such as ancestral Hopi and ancestral Havasupai, exploiting the region’s resources on a seasonal basis (Sullivan et al. 2001).

Episodes of re-use of FCR features and re-appropriation of salvageable materials from abandoned features such as masonry structures suggest a collective memory of the cultural landscape (Sullivan et al. 2001). Knowledge of what features earlier occupants left on a landscape would have facilitated the re-use and re-purposing of persistent anthropogenic phenomena, and perhaps also have decreased the time and labor cost of collecting the raw materials necessary to establish new features. Abandoned features may have also structured how spaces were utilized by later occupants; thereby reducing time spent planning the most effective means of wild-resource acquisition. Investigating the spatial organization of FCR features in conjunction with other archaeological features may lend insight into the influence that culturally-shared landscape memory had on locations selected for the construction of FCR features.
Statement of the Problem

As of completion of the 2012 field season, 217 FCR features have been documented in the Grand Canyon-Upper Basin region by UBARP, making them the fourth most common type of archaeological phenomena recorded in the study area. Research regarding FCR features of the Upper Basin has centered on their technological role as sites of food production in the local economy, and has included excavation and macrobotanical analysis of some of the features (Cook 1995; Sullivan et al. 2001). The spatial distribution of FCR features and their relationships to other archaeological features in the study area have yet to be systematically examined.

An exploratory spatial analysis of the FCR features is warranted given the significance of these features in the subsistence strategies of prehispanic groups occupying the area, their unprecedented presence in this region, and their inferred episodes of re-use. The present study employs Geographic Information Systems (GIS) to investigate the extent to which environmental factors such as elevation, slope, and aspect, and other factors such as locations of abandoned archaeological features, influenced the placement of FCR piles and scatters in the Upper Basin. Additionally, exploring the spatial pattern of FCR features may provide insight regarding their formation and use histories.

The objective of this investigation is to explore whether any patterns or combination of relevant environmental or spatial attributes recur in the arrangement of FCR features and their neighboring anthropogenic features. The archaeological feature type that occurs closest to FCR features will also be identified, as it may be indicative of re-appropriation and re-use of abandoned phenomena. Results of this study may allow for future research questions to be
formulated and evaluated regarding the use of space and how it relates to subsistence strategies of the prehispanic residents of the Upper Basin.

*Spatial Analysis and GIS in Archaeology*

The unique spatial and temporal resolution of archaeological data places archaeologists in a singular position to investigate complex cultural processes that have considerable time depth and extensive spatial properties. Spatial analysis has long been employed by archaeologists to explore the dynamic relationship between human cultures and the natural environment. Exploration of the spatial aspects of human-environment interaction is essential to investigations and efforts to explain the developmental processes of human behavioral adaptations in a particular setting (Dean and Doyel 2006:1-5). Climate, resource availability, physical geography, and the nature of social interactions with other cultural groups are all factors that have a spatial dimension and may be explored in attempts to understand how landscapes are perceived and organized by their inhabitants. Investigations that incorporate space as a principal unit of inquiry traditionally have tended to focus on broad regional issues such as patterns of settlement distribution, chronologies, and trade networks; and they have varied in their interpretations of the natural environment from a passive stage on which the drama of human existence is played out to playing a deterministic role in the nature and development of human adaptations (Knapp and Ashmore 1999).

The spatial analysis of archaeological phenomena, in the form of the study of settlement patterning, expanded in the “New Archaeology” of the 1960s and 70s utilizing an open-system ecological approach (Watson and Fotiadis 1990:614). Open-system ecology differs from deterministic ecology in that it conceives of cultural systems as adaptations to “a total
environment” composed of both the natural setting and other cultures. This holistic approach presumes that aspects influencing any single element of a sociocultural system will ultimately impact other elements of the system and thereby affect the system’s relationship with the natural environment (Trigger 1971:329-331). Using this approach, archaeological remains came to be viewed as representative not only of how environmental conditions influenced development of and adaptations within cultural systems, but also as reflective of all factors, both environmental and social, that affect the system as a whole (Binford 1983:105).

As the spatial patterning of settlements, individual features, and artifacts acquired new significance in approaches that emerged in the latter half of the twentieth century, geographical approaches to the study of prehistoric cultures were increasingly incorporated into archaeological research. The exploration of spatial pattern analyses has since advanced in the discipline by integrating approaches such as historic landscape and prehistoric settlement archaeologies into investigations regarding the use and perception of space (Knapp and Ashmore 1999:2). These approaches consider the complex nature of how humans perceive landscapes as integral to understanding settlement patterning and ecological dynamics (Kantner 2008:59; Trigger 1989:282; Yamin and Metheny 1996:8). Archaeological studies have more recently implemented spatial analyses as a means to investigate diverse topics that range from the conceptualization and symbolic meaning of spaces to the life histories of anthropogenic features and places (Ashmore 2002:1172).

Over the past few decades, advances in geographical information systems (GIS) have furthered the interpretive potential of spatial analyses of archaeological data. GIS techniques have equipped archaeologists with unparalleled modeling capabilities with which hypotheses founded on spatially referenced data can be conceptualized and evaluated (Kantner 2008:49).
Spatial analysis using geographic visualization techniques has proved valuable in identifying meaningful archaeological patterns on both intersite and intrasite scales (Hill 2004; Stine 2000).

The identification of spatial patterns and relationships that exist among archaeological phenomena and environmental conditions does not in itself offer explanations relative to the generative processes associated with the origins of archaeological phenomena (Fitzjohn 2007; Kantner 2008). Reconstructing human behavior on the basis of spatial analyses of archaeological phenomena also presents problems unique to the discipline because of the nature of archaeological data, which are subject to data-recovery biases that are both embedded in research agendas and magnified by incomplete preservation of archaeological materials (Hodder 1972:228). Identifying and exploring spatial patterns and relationships does, however, allow the archaeologist to formulate and test hypotheses regarding the behavioral processes that correlate with the archaeological features and their associated land-use patterns (Hill 2004:390; Kantner 2008:49; Stine 2000:62). Spatial analysis in archaeology is, therefore, best used as an exploratory method that may reveal general patterns in spatial data. This study will implement a GIS-based approach to conduct an exploratory spatial data analysis regarding the distribution of FCR piles and scatters as features that were integral in the subsistence economies of the ancient occupants of the Upper Basin. Spatial analysis of the FCR features has the capacity to generate hypotheses and answer future research questions regarding the behavioral processes associated with their construction, cycles and duration of use, and eventual abandonment in the Upper Basin.
Organization

Following this introductory chapter, Chapter 2 will provide background on FCR features documented in the UBARP study area. Previous studies conducted by UBARP regarding the FCR features and associated artifacts, including macrobotanical analysis are outlined.

Chapter 3 focuses on the research methodology of this thesis and UBARP methodology that pertains to the compilation of data used in this exploratory spatial investigation. The GIS methods and techniques used in this study are provided as well as the rationale for decisions regarding the selection of specific techniques. A considerable amount of the study area lies within the boundaries of Kaibab National Forest; therefore designations made by the USDA Forest Service, referred to as Terrestrial Ecosystem Survey (TES) units, will be examined and considered with respect to potential influence in FCR feature locations.

Results of analyses are discussed in Chapter 4. Statistical verification is provided for those patterns visually identified in the data exploration with GIS. The influence that environmental variables may have had on the spatial arrangement of anthropogenic phenomena is evaluated. Additionally, patterned spatial relationships among various types of archaeological phenomena are explored and discussed.

The closing chapter of this thesis, Chapter 5, discusses findings and interpretations of the spatial analyses. Some inferences regarding the land-use patterns associated with prehispanic groups occupying the Upper Basin, and possible questions for future research based on UBARP spatial data will be offered. And finally, drawing from results of all analyses, conclusions are drawn regarding the environmental and cultural factors that appear to have influenced the placement of FCR features.
Chapter 2: Background

Introduction

Several decades of survey and excavation in northern Arizona conducted by UBARP have documented 217 FCR piles and scatters, dating between C.E. 750 and 1200 (Sullivan et al. 2001:376). FCR is the by-product of rocks having been exposed to very high heat, then undergoing a cooling phase that results in distinct angular fracturing (Thoms 2009). In an archaeological context, FCR is commonly associated with cooking and processing of food resources in bulk quantities for immediate consumption or short to long-term storage (Eerkens et al. 2002). In the Upper Basin region, FCR features were used by perennial and seasonal occupants specifically in the context of processing undomesticated, edible plants in a subsistence economy reliant on wild resource exploitation (Sullivan et al. 2001:376). This chapter describes the context of FCR features in the Grand Canyon-Upper Basin region, and includes a description of the study area, descriptive statistics for the FCR features, and a summary of previous research regarding the features under investigation.

The Study Area

The UBARP study area, 23.8 km², lies within northern Arizona’s Upper Basin, south of the South Rim of the Grand Canyon on the Coconino Plateau, where elevation ranges from 1,860 m asl at the Plateau’s base to 2,256 m asl along the Grand Canyon’s South Rim (Figure 1) (Sullivan et al. 2001:367). Precipitation in the Upper Basin occurs primarily during winter and summer yielding an annual rate of about 15 inches (Bayman and Sullivan 2008:12). Winter precipitation comes in the form of either snow or scattered rains that can last several days.
During the summer months, powerful thunderstorms tend to concentrate rainfall in localized areas (Fugate 2003:10). Little rain falls during the late spring, early summer, and early autumn (Bayman and Sullivan 2008:12). The Upper Basin’s seasonal cycles are marked by warm summers with a mean temperature of around 70° Fahrenheit, and cold winters with a mean temperature of approximately 30° Fahrenheit (Fugate 2003:10).

Figure 1. UBARP study area in northern Arizona.
The Upper Basin is an upland pinyon-juniper zone comprised of dense woodlands and sporadic patches of sagebrush-grasslands (Bayman and Sullivan 2008:12). Pinyon pine trees outnumber juniper trees in the Upper Basin, though both have a low moisture requirement and a high tolerance to drought, and therefore thrive in this semi-arid climatic zone (Fugate 2003:12).

The Upper Basin was most densely occupied from C.E. 850 to C.E. 1200 by Cohonina and Anasazi groups (Sullivan and Ruter 2006). After C.E. 1200, the Upper Basin was no longer inhabited perennially, but was used seasonally by Hopi and Havasupai peoples (Sullivan et al. 2001:376). FCR features are present for all periods of use and habitation based on ceramics (Bayman and Sullivan 2008:13). Many of the ceramic sherd scatters associated with the FCR features and throughout the study area contain a mix of ware types representative of the various cultural groups that inhabited the region (Szeghi 2012). The “mixed” artifact assemblages are attributable to overlapping occupational episodes and re-use of ceramic sherds in various contexts (Cook 1995; Sullivan et al. 2001).

**Physical description of FCR features**

This section summarizes the physical properties of the FCR piles and scatters that have been documented in the UBARP survey database as of completion of the 2012 field season. FCR features exhibit considerable variation in terms of size, shape, composition of clasts, and configuration of associated artifact scatters. This degree of variability is indicative of gradients of use or cycles of use (Sullivan et al. 2001; Thoms 2009).

Length and width measurements were recorded for 92 percent of the FCR features in the study area (n=200). Although the lengths and widths of the FCR features have normal distributions, they are highly variable with minimum and maximum values ranging between 1 m
and 14.8 m for length and 0.8 m to 11 m for width. Mean feature length and width values are approximately 4.1 m and 2.9 m respectively (Figures 2 and 3). Statistical analysis of FCR feature lengths and widths (n=200) indicates a strong positive correlation between these two variables (r = .850, p < .001).

![Figure 2. FCR feature length (m) histogram.](image)

**Mean** = 4.09  
**Std. Dev.** = 1.70  
**N** = 200
The composition of the FCR clasts that constitute features is diverse with respect to color, from black to bluish-white, and rock size, ranging from small, gravel-sized chunks to large cobble fragments, both of which reflect the degree of thermal-alteration (Cook 1995; Sullivan et al. 2001; Thoms 2009). The verticality of the FCR features exhibits a considerable degree of variability, ranging from near-surface diffuse scatters to concentrated mounds of FCR (Cook 1995:23). Mound height of FCR features varies between approximately 10 and 50 cm from the ground surface (Sullivan et al. 2001:368-369). There is an inverse relationship between the dimensions of FCR features and the sizes of the clasts comprising them. Clast size decreases and becomes more uniform as the FCR feature becomes increasingly mounded, indicating multiple episodes of heating as fracturing increases with increased exposure to heat (Cook 1995:30). Thus, variation in mound height is attributable to intensity of feature use. Diffuse scatters of FCR
are therefore inferred to have been used less intensively than the more concentrated and mounded FCR piles.

Previous Studies of FCR Features

Experimental studies of thermal-alteration of rocks, which were heated to 800°C and then allowed to slowly cool over a 48 hour period to simulate various systemic use contexts, produced intensive cracking, oxidation, and bulk density loss (Thoms 2007:486). Exposure to extremely high heat and subsequent cooling are processes that produce the intense fragmentation of thermally-altered rocks, and the more episodes of heating and cooling, the more fracturing occurs, resulting in assemblages of smaller clasts (Cook 1995:19-23). The use history of FCR features, as registered by the size and composition of clasts comprising the piles and scatters, contributes significantly to variations in the length, width, and mound height of the features themselves (Thoms 2009:588).

FCR features of the Upper Basin are the archaeological consequence of an economic technology that involved rocks having been placed over hot coals in order to absorb heat, thus reducing the need for additional fuel, then intermittently scattered and churned about as needed to maintain thermal conduction during the processing of plant resources (Sullivan et al. 2001:370). Excavation of a sample of FCR features in the Upper Basin revealed that they lie directly upon thermally-altered, prehistoric surfaces (Sullivan et al. 2001:378). Subsequent macrobotanical analysis of samples recovered from the excavated FCR features further substantiates inferences regarding their economic role in wild-plant processing, especially the seeds of cheno-ams (Figure 4) (Cook 1995; Sullivan et al. 2001; Sullivan and Ruter 2006).
Figure 4. Macrobotanical analysis of samples recovered from MU 236, an excavated FCR feature.

Composition of Artifact Scatters Associated with FCR Features

Twenty-seven percent (n=58) of the documented FCR features have ceramic sherds in direct association, and ceramic sherds were recovered from all excavated FCR features (Figure 5) (Cook 1995). Ceramic sherds associated with FCR features were in all likelihood used at the activity sites in sherd form due to the fact that intact vessels were neither found in association with the features nor could be reconstructed from the sherds recovered at the sites (Sullivan 1992). Potsherds used as “trays” on which to parch seeds to better facilitate the roasting process may account for the presence of sherds associated with FCR features (Cook 1995; Thoms 2009). The composition of the associated ceramic sherd assemblages may be explained by scavenging and re-use in numerous contexts by various groups at different times. Moreover, if intact vessels ever were used at these sites they would have been transported, once filled with the processed
resources (i.e., seeds and nuts), to be stored elsewhere (Sullivan et al. 2001:376). Also, if whole vessels were broken in the course of their being used at the processing sites, it is likely that the resultant sherds would have been transported to another activity area to be re-purposed in any number of contexts (Cook 1995:160).

Figure 5. Ceramic wares associated with FCR features.

Lithic and ground-stone artifact scatters are invariably associated with FCR features; however they are diverse in their assemblage compositions (Cook 1995; Sullivan et al. 2001). Variation in FCR lithic assemblages can be explained by differences in intensive and non-intensive tool production episodes (Cook 1995:163). The proximity of lithics to FCR features
suggests that these features were in multi-functional areas where occupants engaged in activities that included both the processing of edible resources and tool production, and most likely other activities (Sullivan et al. 2001).

Associated ground-stone artifacts are primarily fragmentary and often exhibit evidence of re-sharpening (Figure 6). Variation in the extent of re-sharpening reflects the degree to which the ground-stone artifact was re-used; metates may also have been reduced in size in order to lighten their weight for transport (Cook 1995:171-174). The omnipresence of ground-stone artifacts in close proximity to FCR features further indicates their primary function as edible-plant processing features (Sullivan et al. 2001).

![Figure 6. Ground stone fragments adjacent to an FCR pile in UBARP study area.](image)
Chapter 3: Methodology

Introduction

This chapter discusses the methods used to explore factors that may have influenced the placement of FCR features. The primary objective of spatial analysis is to reveal patterns embedded in the data under investigation (Goodchild 2004:712). In this study, analyses of environmental factors, such as slope, elevation, and distribution of FCR features within the Terrestrial Ecosystem Survey units of Kaibab National Forest, which occur in the confines of the study area, were conducted to assess the degree to which prehispanic groups might have favored or avoided specific environmental qualities in the placement of FCR features. To reveal the spatial distribution of the FCR features and their relationship to other archaeological phenomena, nearest-neighbor analysis and near-distance analysis were conducted. An overview of UBARP survey methods is presented first, followed by the methods used in this study.

Survey Methodology for FCR Features

The UBARP survey database has been constructed over several decades of research. Field surveys were conducted by crew members spaced 10 m apart walking collectively along transects (Szeghi 2012: 16). A Global Positioning System (GPS) point was recorded each time a FCR feature was identified. Other data such as feature length and width measurements, primary ware, and geophysical variables such as sedimentation and erosion, which may affect the dimensions and intactness of FCR, were also recorded in the GPS file. GPS points collected were differentially corrected daily using Trimble’s Pathfinder software to download base station files containing the positions of a known datum point against which an error calculation was made for
the original GPS point; corrected points representing FCR features were then integrated into the UBARP survey database.

In order to avoid subjectivity and the functional assumptions that traditional designations of archaeological phenomena often imply, UBARP assigns an interpretation-neutral “mapping unit” (MU) when archaeological materials are encountered. This system discourages hasty functional interpretations and the premature groupings of various archaeological phenomena under the aegis of a single “site” as each phenomenon is assigned its own MU number (Sullivan et al. 2007). FCR and other archaeological features used in this study contained a classification value in the variable field labeled “type” within the survey database, which corresponds to a feature type defined by UBARP protocol.

**GIS Data and Methods**

This investigation employs the Spatial Analyst and the Spatial Statistical toolsets of ESRI ArcGIS 10.0 to determine the dispersion and possible spatial interactions of the 217 FCR piles and scatters, and nearby archaeological phenomena. The 2012 UBARP survey database was used to generate maps and individual shapefiles (non-topological digital data models for storing geometry and attribute information of geographic features) of MU types, so that the spatial patterns of and relationships among varying types of archaeological materials could be visualized and explored (Demers 2009:116). The spatial patterns observed through geographic visualization of mapped features were quantified by the application of statistical analyses. Statistical analyses provide a means to evaluate if observed spatial patterns are the result of random chance. Calculated probabilities of observed archaeological feature distributions allow for comparison and exploration of spatial relationships among material remains (Conolly and Lake 2006; Grier
and Savelle 1994; Knowles 2000; Merrill and Read 2010; Whallon 1973). Attribute and location queries of feature layers in ArcMap provide additional means with which observed spatial interactions and patterns might be investigated.

Spatial analysis tools in ArcGIS were selected for their potential in revealing two different types of spatial patterning: spatial clustering and compositional patterning (Ferring 1984:116-126). Spatial clustering, also referred to as density patterning, considers the frequency of occurrence of archaeological remains over the areal extent under investigation (Grier and Savelle 1994). This type of analysis is effective in identifying clustering at various scales, and it is commonly used to define site boundaries and to explore spatial patterns within and among archaeological phenomena (Bevan and Conolly 2002; Hill 2004; Hunt 1992; Merrill and Read 2010; Whallon 1974). Compositional patterning refers to the distinct spatial distribution of selected types of archaeological materials and considers the spatial co-association of the features independent of their clustering tendencies (Conolly and Lake 2006; Hill 2007; Robinson 2010). Nearest-neighbor analysis, a component of the ArcGIS Spatial Statistical Analyst toolset, facilitates the measurement of geographic clustering patterns among point data in a given area (Hill 2004:395; Lawson 2007:92; Merrill and Read 2010:421). The Near tool, part of the Proximity toolset, is used to interrogate the compositional patterning and co-occurrence among FCR features with other types of anthropogenic remains, as it calculates the distance from each point in one data set to the nearest point of any other specified data set.

To evaluate the influence of environmental factors on the spatial distribution of archaeological features, a digital elevation model (DEM) for the study area was used to conduct elevation, slope, and aspect analyses. Additionally, a TES unit shapefile and its attribute table
were queried to assess the distribution of and spatial relationships among archaeological phenomena within various TES units.

*Nearest-Neighbor Analysis Methodology*

Nearest-neighbor analysis is used to quantitatively determine if distributions of points representing archaeological features occur in a random or non-random pattern. The statistic generated by nearest-neighbor analysis represents a ratio of the observed average distance among points, and the expected average distance of the same points given a random distribution (Lawson 2007:92; Merrill and Read 2010:421). Nearest-neighbor analysis is most applicable and reliable when the area under investigation has fixed boundaries (Hill 2004:395; Knowles 2000:452; Whallon 1974:22). For this reason, nearest-neighbor statistics were generated for each polygon comprising the study area that contained a significant number of FCR features. Comparison of average nearest-neighbor coefficients enables detection of deviations in the spatial clustering of FCR features from the clustering pattern of other types of archaeological remains (Grier and Savelle 1994:99; Lawson 2008:91-95; Whallon 1973:266-267). In this investigation, nearest-neighbor analysis was conducted to reveal the spatial pattern of FCR features and compare it to those of other MU types identified in the study area.

Nearest-neighbor analysis in ArcGIS results in the output of observed mean distance of points, expected mean distance of points in a random distribution, nearest-neighbor index, a Z-score, and a critical p-value. The returned Z-score and p-value indicate whether a null hypothesis of random distribution can be rejected. The p-value represents the probability that the observed spatial pattern is the consequence of some random process. A low p-value (less than one percent) indicates that the observed spatial pattern is not the result of random chance. The Z-score
represents standard deviations from the mean. Z-scores less than one indicate a clustered spatial pattern, whereas scores greater than one indicate a dispersed spatial pattern. In either direction (negative or positive), the further away from 1 that a Z-score is, the more pronounced the pattern, whether it be clustered or dispersed. For the nearest-neighbor analysis calculation formula, see Appendix A.

Near-Distance Analysis Methodology

Near analysis, located in the Proximity toolset of ArcGIS, was used to further investigate the spatial configuration of the FCR features in relation to other types of archaeological phenomena. This analysis facilitates exploration of spatial interaction within and among point feature types (Demers 2009:45). The Near tool locates and identifies the nearest point feature in the same or another feature layer of point data. The search radius is specified by the user. The results returned from a Near analysis appear in the input feature’s attribute table as two fields with numeric values that indicate the unique feature identifier and the distance from the input feature to the nearest feature in the layer queried in the linear unit of the input layer’s coordinate system.

Near-distance analyses were generated for FCR and other MU types with an initial specified search radius of 30 m. Thirty meters was considered an appropriate search radius to explore spatial interaction given the clustered nature of the FCR features in the study area, and the labor and time investment required to transport raw materials used to establish the features (i.e., a considerable quantity of large rocks). Near-distance analyses with a search radius increasing in 10 m increments to a search radius of 100 m were also generated to allow for comparison of patterns at different scales of analysis, and to assess changes in spatial
configurations and interactions of FCR features and other MU types of interest over increasing distances.

Microsoft Visual Studios 2010 was used to create a unique drop-in tool that was then loaded into ArcMap. A dialog window was designed to mimic that of the Near tool as it presented the same variables to be specified. Drop-down windows in the dialog box for input and near features contained the 2012 UBARP shapefiles for the MU types under consideration. This interface allowed for expeditious calculation and comparison of multiple Near analyses. A drop-down window was also created for the search radius to be selected at varying distances in meters. Finally, the tool was programmed to create buffers around points in the input feature layer identical to the specified search radius upon completion of the Near analysis to allow for better geographical visualization of spatial patterns.

Elevation Methodology

To explore possible environmental variation that may have influenced the placement of FCR features in the UBARP study area, topographical variables were calculated and examined in ArcMap. Digital elevation models (DEMs) are raster data embedded with an elevation value for each cell (Conolly and Lake 2006:5; Kvamme 1989:158). For this study, a United States Geological Survey (USGS) DEM of northern Arizona with a spatial resolution of 10 m was downloaded and clipped using the Extraction by Mask tool for the UBARP study area (Figure 7). The resulting DEM was used to calculate slope and aspect for the study area.
Slope Analysis Methodology

The Slope tool is a component of the surface analysis toolset in ArcGIS. Slope may be defined as an angle or vertical rise over horizontal run or reach. Slope is a neighborhood function.
that is calculated using raster data from a grid of elevations or a DEM. The GIS method for
deriving slope fits a plane through the eight immediate neighboring cells of the target cell by
finding either the greatest or average slope value for the neighborhood of grid cells; for each
group of cells the grid cell resolution is used as the measure of distance to which the elevation
values from the central cell are compared to those values of the surrounding cells. The
percentage of a slope is determined by the following formula: slope percent = (rise/run) x 100
(DeMers 2009:272-275). A slope percent of less than five corresponds to flat or nearly flat
terrain, while slopes classified as 30 percent or greater are considered very steep.

Aspect Analysis Methodology
   Aspect refers to the compass direction to which a slope is oriented (Mires 1993:82). It is
measured clockwise in azimuthal degrees where both 0˚ and 360˚ correspond with true north.
When a flat surface is encountered a value of -1 is assigned to indicate lack of slope and
therefore no aspect was designated. As with slope analysis, aspect analysis is calculated using
raster data from a grid of elevations or a DEM. Located in the surface analysis toolset of the
ArcGIS toolbox, the Aspect tool calculates the direction in which a plane fitted through the slope
faces for each cell by determining the maximum rate of change in value from each cell to its
neighbors (DeMers 2009:273-275). Thus, aspect is, like slope, a neighborhood function. In this
study, aspect is calculated to determine if the orientation of slopes on which FCR features are
located diverges from the aspect of slopes throughout the study area.
Methodology of Analysis using Terrestrial Ecosystem Survey Units

Terrestrial ecosystem units are characterized by various attributes relative to climate, vegetation and soil composition. The ecological units were designated as part of the Terrestrial Ecosystem Survey of Kaibab National Forest (TES) conducted by the USDA Forest Service to predict and assess soil erosion and vegetation productivity potential (Brewer et al. 1991). A shapefile containing the TES units was downloaded from the Kaibab National Forest website and clipped using the boundaries of the UBARP study area shapefile to examine the influence of various TES unit attributes on FCR feature placement. The UBARP study area encompasses only ten of the more than 130 TES units that make up Kaibab National Forest, and of those ten, two constitute more than 62 percent of the study area (Szeghi 2012; Uphus 2003). The Kaibab National Forest accounts for approximately 80 percent of the total UBARP study area; 71 percent of all documented MUs and 84 percent of FCR features are located within Kaibab National Forest boundary.
Chapter 4: Results of Analyses

Introduction

This chapter presents the analytical results and considers the environmental and cultural factors affecting the spatial distribution of FCR features. First, results of analyses regarding environmental factors (elevation, TES units, slope, and aspect) are presented along with their potential influence on the spatial distribution of FCR features. Second, results of nearest-neighbor analysis and near-distance analysis of FCR features and other archaeological phenomena in the study area are discussed. Third, the spatial relationships, as revealed in these analyses, of FCR features and other MU types are summarized. Finally, evidence for the influence of environmental and cultural factors on the spatial arrangement and formation histories of FCR features is evaluated.

Elevation Analysis Results

The mean elevation for all MU locations documented in the study area is approximately 2,094 m asl. The elevation range for the 217 FCR feature locations has a pattern similar to that of all other MU types with a mean elevation of 2,090 m asl. An independent samples t-test was conducted to compare mean elevation values for FCR features and all other MU types. The results indicate that there is no statistically significant difference between the two means given a probability value greater than .05 (Table 1). The influence of elevation in the placement of all anthropogenic phenomena, including FCR features, is inconsequential given that elevation values exhibit little variation throughout the entire study area (Figure 8).
Table 1. Results of independent samples t-test to compare elevation means of FCR features and other MU types.

<table>
<thead>
<tr>
<th></th>
<th>Cases</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>t</th>
<th>Degrees of Freedom</th>
<th>Probability (2-tailed Sig.)</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCR Features</td>
<td>217</td>
<td>2090.5</td>
<td>66.97</td>
<td>-.688</td>
<td>277</td>
<td>.492</td>
<td>-3.33</td>
</tr>
<tr>
<td>All Other MU Types</td>
<td>1864</td>
<td>2093.8</td>
<td>71.74</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 8. Contour elevation map of the study area.
Terrestrial Ecosystem Survey Units Analysis Results

The two TES units that comprise the largest portions of the study area within Kaibab National Forest boundaries are 260 and 263 (Figures 9 and 10). Together these units constitute approximately 62 percent of the study area. TES units 260 and 263 contain 41 percent and 33 percent respectively of the 182 FCR features located in the national forest. For all documented MUs, TES unit 260 has the highest frequency of occurrences (n=537) and comprises approximately 19 percent of the study area within the national forest boundary, while TES unit 263 contains 501 documented MUs and makes up approximately 43 percent of the study area in the national forest (Table 2). TES units 260 and 263 have the dominant vegetation type of pinyon and juniper woodlands and share the soil taxon of lithic ustochrepts, the most common type in the study area, which is a subgroup of the inceptisols soil class, characterized by weakly developed horizons, mesic soil temperature, and a ustic moisture regime with lithic contact (Brewer et al. 1991). In contrast, the two units are dissimilar with respect to erosional processes and vegetation productivity under climax conditions (Brewer et al. 1991; Uphus 2003:76-77). Interestingly, TES unit 260 has higher values both for cords of fuelwood per acre (12.5), and vegetal groundcover under climax conditions (65 percent) than TES unit 263, which has values of only five cords of fuelwood per acre and 40 percent vegetal groundcover under climax conditions (Brewer et al. 1991; Uphus 2003:39-40).
Figure 9. Bar chart showing percents of the study area and FCR features in TES units.

Figure 10. Study area and Kaibab National Forest TES units.
Examination of the influence of TES units on the location of all MUs revealed that certain TES unit attributes, such as available cords of fuelwood per acre and vegetal groundcover productivity may have influenced their locations to some extent. Regarding FCR feature location, abundant fuel is crucial to sustaining fires that reach temperatures high enough to maintain thermal conduction in processes involving FCR (Thoms 2007). Macrobotanical samples recovered from excavated FCR features in the study area all contained the charred...
remains of pinyon and juniper, indicating their use as fuel (Cook 1995: 174). The qualities, fuelwood per acre and groundcover vegetation productivity, are indicative of the potential abundance of fuel available in a TES unit, which may have been influential factors in the placement of all documented MUs, including FCR features, as abundant fuel would have been a persistent necessity for the region’s occupants.

Uphus’s (2003) analysis of the influence of TES units on the selection of locations for masonry structures found that TES unit 260 was preferred between C.E. 1000-1070, whereas TES units 263 and 250 were preferred in both the preceding and successive time periods. These two TES units contain the second and third highest frequencies of FCR features, with 33 and 14 percent respectively. The similarities in the spatial patterns of masonry structures and FCR features within TES units may indicate land-use persistence and re-purposing of materials that comprise both feature types (i.e., rocks). For example, abandoned masonry structures may have served as resource patches from which rocks could be salvaged for the establishment of FCR features, thereby attracting later inhabitants to previously used landscapes. Nearest-neighbor and near-distance analyses allowed for the spatial relationship of FCR features and masonry structures to be further explored and is discussed later in this chapter.

*Slope Analysis Results*

The study area is largely composed of gradual slopes with a gradient less than 10 percent (Table 3). Forty-eight percent of all documented MUs and 53 percent of FCR features are located on flat or nearly flat terrain where slope gradient is less than 5 percent. Examination of slope analysis and locations for all documented MUs (including FCR features) demonstrates a negative correlation between slope percent and occurrence of archaeological remains (Figures 11 and 12).
The presence of archaeological phenomena declines considerably after slope value exceeds ten percent. This pattern is demonstrated by the fact that the occurrence of all archaeological phenomena is 33 percent where slope percentage ranges from six to ten, but decreases to 10 percent where slope percentage ranges from eleven to fifteen. The slope analysis of FCR feature locations revealed a similar trend with the frequency of features declining significantly after slope value exceeds ten percent. Thirty-four percent of FCR features occur where slope percentage ranges from six to ten, and only 0.09 percent of FCR features are located on slopes ranging from eleven to fifteen percent. Not surprisingly, level terrain or gradual slopes were preferred for locations of all MU types as flat topography best facilitates most activities.

Table 3. Description of slope percent.

<table>
<thead>
<tr>
<th>Slope Percent</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>Flat Terrain</td>
</tr>
<tr>
<td>6-10</td>
<td>Gradual Slopes</td>
</tr>
<tr>
<td>11-20</td>
<td>Moderate Slopes</td>
</tr>
<tr>
<td>21-30</td>
<td>Steep Slopes</td>
</tr>
<tr>
<td>&gt; 30</td>
<td>Very Steep Slopes</td>
</tr>
</tbody>
</table>
Figure 11. Histogram of slope analysis for FCR feature locations in the study area. No FCR features are located on slopes greater than 30%.

Figure 12. Histogram of slope analysis for all documented MU (including FCR features) locations in the study area.
Analysis of Slope and TES Units

A map layer comprised of the TES units was overlaid on the slope analysis map layer to better facilitate geographic visualization and pattern identification. This method allowed for slope values and point features representing archaeological phenomena to be extracted and assigned to their corresponding unit (Table 4).

Table 4. Slope designation for TES units containing FCR features and more than 5% of all MUs in Kaibab National Forest.

<table>
<thead>
<tr>
<th>TES Unit</th>
<th>Slope Designation</th>
<th>Percent of FCR Features (n=182)</th>
<th>Percent of All MUs (n=1540)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>Gradual to moderate slopes &gt;14%</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>260</td>
<td>Flat terrain to gradual slopes &gt; 10%</td>
<td>41</td>
<td>35</td>
</tr>
<tr>
<td>263</td>
<td>Flat terrain to gradual slopes &gt; 10%</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>272</td>
<td>Gradual to moderate slopes &gt;20%</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>683</td>
<td>Flat terrain to moderate slopes &gt;20%</td>
<td>1</td>
<td>.008</td>
</tr>
</tbody>
</table>

Archaeological phenomena occurring in TES unit 272 are densely concentrated in a narrow, central portion of the study area that lies between TES units 260 and 23 and is comprised of gradual slopes of less than 10 percent (Figure 13). Archaeological remains occur rarely in TES unit 23 (5 percent of all MUs) and other portions of TES unit 272. Because other portions of TES unit 272 lack archaeological features situated on gradual rather than moderate slopes, the dense clustering of MUs suggests that the placement of the FCR features there may have been...
influenced by factors other than attributes associated with TES unit designations, such as the presence of previously abandoned features. Abandoned FCR features were likely re-used or scavenged for salvageable materials by groups occupying the region in later time periods (Barton et al. 2004:278; Sullivan et al. 2001:376).

Figure 13. Map of clustered MUs in TES unit 272 and adjacent units.
Aspect Analysis Results

Aspect analysis performed on FCR features in the study area revealed a tendency for south and southeast oriented slopes (Figure 14). FCR features are evenly distributed on slopes oriented to the south and southeast, with both aspect categories containing 61 features. To determine if the orientation pattern of FCR feature locations differs from the natural aspect distribution of the study area, a histogram of slope orientation throughout the study area was generated (Figure 15). The results indicate that the pattern of FCR feature locations does not differ from the orientation of slopes throughout the study area. Aspect is therefore not considered influential in FCR feature locations.

Figure 14. Histogram of aspect of FCR feature locations.
Figure 15. Histogram of aspect for the study area. Count represents the number of raster cells in each class. The mean aspect is 170°.

*Nearest-Neighbor Analysis Results*

The average nearest-neighbor statistic is sensitive to the extent of the area under investigation (Hill 2004:395). Nearest-neighbor analysis is, therefore, most effective when the study area is specified by the user. If the area value parameter is not specified, the value calculated for the total area of a rectangle, in which all of the input features are enclosed, is used as the study area value. With this consideration in mind, and because of the space between polygons comprising the study area, the GIS Calculate Area tool was used to determine the area of the two polygons used in the nearest-neighbor and near-distance analyses. The UBARP study area is comprised of one large polygon, which makes up approximately 90 percent (21.4 km²) of the study area, and six satellite polygons. The two polygons used in this analysis contain 96
percent (n=208) of the FCR features, and are labeled and referred to as “main” and “north” (Figure 16).

Figure 16. Map of polygons used in nearest-neighbor analysis.
The nearest-neighbor statistic indicates whether the spatial pattern for a distribution of points is clustered, random, or dispersed. Nearest-neighbor analyses were conducted for FCR features and three other MU types so that comparisons of spatial distributions could be made. As previously discussed, re-use and scavenging of materials from abandoned archaeological features may have influenced FCR feature locations. Since rocks of a suitable size for FCR feature use are the primary components of masonry structures and non-FCR rock piles, their spatial distributions were relevant to this investigation. Lithic scatters (n=918) were selected for nearest-neighbor analysis because of their ubiquity throughout the study area, particularly in the polygons under investigation. Masonry structures are the second most commonly occurring type (n= 371). Ninety-one non-FCR rock piles have been documented in the study area, 42 of which are in the main polygon and 21 in the north polygon.

Results of analysis of FCR feature distributions in both polygons indicates highly clustered spatial patterns with less than one percent probability that random chance could account for such clustering. Nearest-neighbor analysis results for the other three MU types in both the main and north polygons revealed that each type has a statistically significant clustered spatial pattern (Tables 5 and 6). Results of analysis for masonry structures in the main polygon revealed a highly clustered spatial pattern similar to that of FCR features, non-FCR rock piles, and lithic scatters. In the north polygon, however, masonry structures are less clustered than the other MU types. Non-FCR rock piles and lithic scatters exhibit a highly clustered spatial pattern in both polygons similar to that of FCR features.
Table 5. Results of nearest-neighbor analysis for MU types in main polygon.

<table>
<thead>
<tr>
<th>MU Type</th>
<th>Number of Cases</th>
<th>Observed Mean Distance (m)</th>
<th>Expected Mean Distance (m)</th>
<th>Nearest-Neighbor Ratio</th>
<th>Standard Deviations</th>
<th>P-Value</th>
<th>Confidence Level Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCR Features</td>
<td>196</td>
<td>88.89</td>
<td>165.13</td>
<td>0.54</td>
<td>-12.37</td>
<td>0.000</td>
<td>99</td>
</tr>
<tr>
<td>Masonry Structures</td>
<td>277</td>
<td>80.68</td>
<td>138.91</td>
<td>0.58</td>
<td>-13.35</td>
<td>0.000</td>
<td>99</td>
</tr>
<tr>
<td>Non-FCR Rock Piles</td>
<td>42</td>
<td>163.74</td>
<td>356.73</td>
<td>0.46</td>
<td>-6.71</td>
<td>0.000</td>
<td>99</td>
</tr>
<tr>
<td>Lithic Scatters</td>
<td>829</td>
<td>60.51</td>
<td>80.29</td>
<td>0.75</td>
<td>-13.57</td>
<td>0.000</td>
<td>99</td>
</tr>
</tbody>
</table>

Table 6. Results of nearest-neighbor analysis for MU types in north polygon.

<table>
<thead>
<tr>
<th>MU Type</th>
<th>Number of Cases</th>
<th>Observed Mean Distance (m)</th>
<th>Expected Mean Distance (m)</th>
<th>Nearest-Neighbor Ratio</th>
<th>Standard Deviations</th>
<th>P-Value</th>
<th>Confidence Level Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCR Features</td>
<td>12</td>
<td>85.13</td>
<td>141.1</td>
<td>0.6</td>
<td>-2.65</td>
<td>0.008</td>
<td>99</td>
</tr>
<tr>
<td>Masonry Structures</td>
<td>33</td>
<td>71.45</td>
<td>85.63</td>
<td>0.83</td>
<td>-1.82</td>
<td>0.07</td>
<td>90</td>
</tr>
<tr>
<td>Non-FCR Rock Piles</td>
<td>21</td>
<td>43.1</td>
<td>107.34</td>
<td>0.4</td>
<td>-5.25</td>
<td>0.000</td>
<td>99</td>
</tr>
<tr>
<td>Lithic Scatters</td>
<td>47</td>
<td>34.21</td>
<td>71.75</td>
<td>0.48</td>
<td>-6.86</td>
<td>0.000</td>
<td>99</td>
</tr>
</tbody>
</table>
Near-Distance Analysis Results

The Near tool, a component of the Proximity toolset, measures the distance of all points in one feature layer to those in another selected feature layer. The spatial patterns for the three non-FCR MU types investigated in the nearest-neighbor analyses were also used for near-distance analysis to explore their relationships with FCR features in the main and north polygons. Near-distance analysis in both polygons revealed that FCR features are located closer to one another than other MU types. The mean distance of the other MU types analyzed to FCR features are all greater than the mean distance of FCR features to one another (Table 7).

Table 7. Descriptive statistics for near-distance analysis for MU types in the main and north polygons. Values represent distance in meters from the MU type to FCR feature locations.

<table>
<thead>
<tr>
<th>MU Type</th>
<th>Main Polygon</th>
<th></th>
<th></th>
<th>North Polygon</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cases</td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Min./Max. Distance</td>
<td>Cases</td>
<td>Mean</td>
</tr>
<tr>
<td>FCR Features</td>
<td>196</td>
<td>89</td>
<td>151</td>
<td>3 - 1028</td>
<td>12</td>
<td>85</td>
</tr>
<tr>
<td>Masonry Structures</td>
<td>277</td>
<td>223</td>
<td>187</td>
<td>1.5 - 782</td>
<td>33</td>
<td>200</td>
</tr>
<tr>
<td>Non-FCR Rock Piles</td>
<td>42</td>
<td>181</td>
<td>151</td>
<td>14 - 484</td>
<td>21</td>
<td>193</td>
</tr>
<tr>
<td>Lithic Scatters</td>
<td>829</td>
<td>207</td>
<td>155</td>
<td>5 - 937</td>
<td>47</td>
<td>114</td>
</tr>
</tbody>
</table>

This pattern suggests that either the placement of FCR features was governed by cultural and behavioral factors related to the delineation of areas for the sole purpose of resource processing, or that these locations were simply more convenient than others for the processing of resources, perhaps due to the presence of previously abandoned features. The location of an
existing FCR feature appears to have been a key determinant if another needed to be established. FCR were likely re-used until they were fractured to an extent that rendered them useless. New features may have then been constructed or existing features replenished with scavenged rocks from nearby phenomena. The fact that suitably-sized rocks are the primary components of the next nearest MU type (masonry structures) at a distance equal to or less than 30 m in both polygons suggests re-use of salvageable materials from abandoned features (Table 8).

Table 8. Near-distance analysis for MU types in main and north polygons. Values represent the number of features within distance categories to FCR features, and percent of associated MU type features within each distance category. Distance is in meters.

<table>
<thead>
<tr>
<th>Input MU Type</th>
<th>Main Polygon</th>
<th>North Polygon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Distance</strong></td>
<td><strong>Distance</strong></td>
</tr>
<tr>
<td></td>
<td>0-30</td>
<td>31-60</td>
</tr>
<tr>
<td>FCR Features</td>
<td>196</td>
<td>90/46</td>
</tr>
<tr>
<td>Masonry Structures</td>
<td>277</td>
<td>52/19</td>
</tr>
<tr>
<td>Non-FCR Rock Pile</td>
<td>42</td>
<td>5/12</td>
</tr>
<tr>
<td>Lithic Scatters</td>
<td>829</td>
<td>51/6</td>
</tr>
</tbody>
</table>

Closer examination of the near-distance values of FCR features to one another lends further insight into their spatial arrangement. The distance value field of the attribute table for FCR features in the main polygon was queried to further deconstruct distances in ten meter increments up to 150 m (Appendix B). Fifty-eight percent of FCR features (n=114) in the main polygon exhibit strong spatial association, occurring within 40 m of one another. Of those
features within the 40 m range of one another, 28 percent are within 10 m, 31 percent fall within
the 11 to 20 m range, 20 percent in the 21 to 30 m range, and 21 percent in the 31 to 40 m range.
After 40 m, the number of features per ten meter increment range drops significantly (Figure 17).
Considering the surface ash and debris that result from use of FCR features, this pattern suggests
that a distance of 11 to 20 m between features was desirable to allow room for activities
associated with the features, which included building a fire, spreading out coals and rocks to
maintain thermal conduction, and processing seeds and nuts. If scavenging of materials was the
only factor influencing the clustered pattern of the features, it seems more likely that the higher
values would occur in the range of 10 m or less, given the time and effort necessary to transport
the rocks.

Figure 17. Histogram of the number of FCR features located within distance increments in
meters to other FCR features in the main polygon.
Summary of Spatial Analyses

Identification of spatial distributions and relationships of FCR features and other MU types provides information regarding the formation histories of FCR features with respect to factors possibly influential in their placement. Environmental factors evaluated included elevation, qualities associated with TES units, slope, and aspect. None of these factors appears to have been significant in the placement of FCR features. Elevation values for all MU types, including FCR features, in the study area exhibit little variation. The occurrence of both FCR features and other types of archaeological phenomena decreases significantly after slope value exceeds ten percent, and the orientation of slopes on which FCR features are located do not diverge from the natural aspects of slopes in the study area. The TES unit qualities, potential fuelwood per acre and potential groundcover vegetation, may have been influential in the location of all documented archaeological phenomena; however, the spatial arrangement of FCR features does not deviate from the pattern of other MU types with respect to these qualities.

The location of previously abandoned archaeological features appears to have been influential in the placement of FCR features. Spatial analyses of FCR features revealed highly clustered distributions that occur closer in proximity to one another than other MU types. Of all non-FCR MU types, masonry structures occur in closest proximity to FCR features within a 30 m radius. Discrete activity areas are not evident, and re-use of salvageable materials from persistent anthropogenic phenomena, especially abandoned FCR features and masonry structures, likely factored into the placement FCR features. The spatial arrangement of FCR features and masonry structures in closer proximity to one another than other MU types is indicative of such re-use.
Chapter 5: Summary and Conclusion

Introduction

This thesis explored and evaluated the influence that the natural environment and behavioral factors may have had on locations selected by prehispanic populations for the establishment of FCR features used to process foraged-plant resources. Since 1995, UBARP has documented 217 FCR features in the Grand Canyon-Upper Basin region. Prior research into the function of FCR features suggested their re-use in wild-plant resource exploitation by inhabitants of the region over a period spanning at least three centuries. Data analyzed in this thesis through quantitative spatial analysis support proposed episodes of re-use of FCR features and other neighboring cultural remains. Furthermore, spatial patterns and relationships of archaeological materials identified in this study lend support to models regarding Upper Basin land use and non-restricted access to the area’s resources (Bayman and Sullivan 2008; Sullivan 1996; Sullivan et al. 2001; Sullivan and Ruter 2006). Additionally, data produced in this analysis may be used to generate and test future hypotheses regarding the manner in which economic-behavioral processes are expressed in spatial patterns of the Upper Basin’s archaeological record.

Summary of Findings

Evaluation of environmental variables included slope and aspect analyses, a comparison of elevation means for FCR features and other MU types documented in the study area, and examination of potential influence of TES unit attributes in the placement of FCR features. These analyses revealed that the natural settings in which archaeological phenomena are most frequently recorded exhibit little variation in terms of elevation level, slope gradient and
orientation, and attributes of Kaibab National Forest TES units. MUs documented in the study area largely occur on flat to gently sloping terrain. Elevation values corresponding to locations of archaeological phenomena are consistent, and the two TES units (260 and 263) containing the highest frequencies of MUs together constitute approximately 62 percent of the study area. The fact that these units compose such relatively large portions of the study area in all likelihood accounts for their high frequencies of archaeological remains. Therefore, attributes of TES units, along with other environmental variables explored were found to be inconsequential in the selection of FCR feature location.

The application of nearest-neighbor analysis revealed that the spatial distribution of FCR features across the study area is highly clustered. Other types of archaeological phenomena investigated included masonry structures, lithic scatters, and non-FCR rock piles, all of which exhibited clustered spatial distributions. Spatial relationships of FCR features and other archaeological phenomena were interrogated using near-distance analysis, which indicate that FCR features occur in closer proximity to one another than to other MU types. Examination of the co-occurrence of FCR features in 10 m increments revealed that the features most frequently occur 11 to 20 m from one another. This pattern suggests that the processing of plant resources at FCR features was a messy business, resulting in smeared ash, charcoal, and other debris up to at least 10 m from the feature’s center, and that features occurring less than 10 m apart were likely established in differing use episodes (Binford 1983:158).

Masonry structures exhibit a strong spatial association with FCR features, occurring in higher frequency than other non-FCR MU types up to a distance of 30 m. Interestingly, the spatial relationship between masonry structures and FCR features is similar to that of the FCR features to one other (Figure 18). The highest frequency of masonry structure occurrence within
30 m of a FCR feature is in the 11 to 20 m range, further demonstrating the space needed to process resources. The distinct spatial relationship between masonry structures and FCR features suggests that suitably-sized rocks were salvaged from abandoned masonry structures for the construction of newer FCR features.

![Graph showing count of FCR features and masonry structures occurring within 10 m distance increments of FCR features.](image)

Figure 18. Graph showing count of FCR features and masonry structures occurring within 10 m distance increments of FCR features.

**Anthropogenic Resource Patches**

The spatial relationships revealed in this analysis are consistent with Sullivan’s (1992) assertion that FCR features were re-used over multiple occupation and seasonal use episodes. Overlapping ceramic periods for assemblages found in association with FCR features further support this finding. In the framework of Schlanger’s (1992) “persistent place” model, the establishment of FCR features on the landscape structured the function of those particular spaces.
for the region’s occupants, as well as for later populations that exploited the area seasonally. Suitably-sized rocks from abandoned features and masonry structures were likely salvaged in the establishment of newer FCR features. Deliberate burning of the pinyon-juniper understory to increase the productivity of edible-plant resources, as proposed by Sullivan (2013), may have allowed for economic planning in the region, and the availability of previously abandoned FCR features would have reduced the labor investment required to construct processing features (Sullivan and Ruter 2006). Evidence supporting re-use by differing populations over time is consistent with a common-pool-resource (CPR) economic system, in which open access was permitted to the Upper Basin’s resources (Bayman and Sullivan 2008). The spatial characteristics of FCR features identified in this analysis, a highly clustered distribution and their relatively close proximity to masonry structures, further supports “persistent place” and CPR models in that abandoned anthropogenic phenomena served as resource patches accessed repeatedly during successive occupation and use episodes (Eerkens 1999; Schlanger 1992; Sullivan 1996).

Re-use of production features through successive temporal periods suggests that environmental factors such as resource abundance and sociocultural factors such as non-restrictive access to resources remained largely stable over the course of occupation and use episodes (Hill 2004). Subsistence strategies of groups in the Upper Basin, which focused on the production and storage of undomesticated resources, were likely more resistant to fluctuations in environmental conditions such as drought and erosion than agriculture-dependent systems throughout the Southwest region (Sullivan and Ruter 2006). Likewise, if social dynamics among groups in and around the region changed, the region may no longer have been open for resource exploitation (Yamin and Metheny 1996). An example of such a change in the nature of relations
among sociocultural groups would be one group claiming ownership of a particular region, thereby limiting the access of other groups. No evidence in the archaeological record of the Upper Basin indicates the development of such practices (Bayman and Sullivan 2008). Rather, spatio-temporal evidence demonstrates that the region was used by differing populations for more than three centuries (Sullivan and Ruter 2006). Data and findings presented here are consistent with this model in that the spatial arrangement of FCR features and their relationship to other MU types across the landscape indicate the attraction or “pull” of abandoned features to later populations to particular spaces, and likely signified to opportunistic newcomers how those spaces were best used and exploited.

**Conclusion and Future Research Suggestions**

The spatial and compositional patterns of varying types of archaeological remains represent the different activities, or behavioral constructs that resulted in the deposition of cultural material (Ferring 1984:117). Once spatial patterns have been detected, the challenge for archaeologists is to formulate hypotheses regarding the behavioral and functional processes to which the observed patterns may be attributed (Hodder 1972). Areas in which specific tasks were carried out are often indistinct as a result of multi-functional use of space and spatio-temporal overlapping of activities; therefore localized spatial patterns, as indicated by the co-occurrence of specific MU types in proximity to one another, were explored in order to reveal economic-behavioral processes that likely influenced FCR feature locations (Merrill and Read 2010; Whallon 1973). Future studies may take a similar approach to explore a range of topics to which the spatial arrangement of specific types of archaeological materials is relevant. One such topic is how gender is expressed in the archaeological record. Consideration of gendered spaces has
increased over the last decade in the study of prehistoric landscapes (Ashmore 2000; Potter 2004). Spatial modeling of locations of artifacts suggestive of gender-specific use, such as metates, may allow for the evaluation of the role gender played in structuring spatial patterns of the Upper Basin’s archaeological record.

Physical properties of FCR features reflect their divergent use histories (Cook 1995; Sullivan et al. 2001; Thoms 2007). Feature dimensions, degree of thermal-alteration evident in clast size, and composition of artifacts found in association with FCR features are all qualities indicative of duration and intensity of feature use. In research regarding FCR feature morphology, Thoms (2009) found that features with a diameter greater than 2 m were used over a period of two or three days, while features with a diameter closer to a meter were used for no more than a day. More in-depth analyses of variations in FCR feature size and morphology are likely to produce data useful for detecting and interpreting functional variations that may exist among features in the Upper Basin.

The periodic re-use and re-purposing of previously abandoned features in the Upper Basin complicates their formation histories. This study has demonstrated the usefulness of exploring the spatial distribution of archaeological phenomena and the relationships among various types of material remains in unraveling aspects of those histories such as the behavioral practices that may account for feature locations. Findings here indicate that the placement of FCR features was influenced by locations of other abandoned features, which were either re-used or used as resources from which suitably-sized rocks were scavenged, thereby cutting time and effort costs for the establishment of newer features. Thus, FCR features may be viewed as remnants of an economic strategy that depended on prehispanic groups’ collective knowledge.
regarding the locations of persistent resources and established features in the Grand Canyon-
Upper Basin region.
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APPENDIX A. ArcGIS formula for average nearest-neighbor analysis.

The Average Nearest Neighbor ratio is given as:

\[ \frac{D_O}{D_E} \quad (1) \]

where \( D_O \) is the observed mean distance between each feature and their nearest neighbor:

\[ D_O = \frac{\sum_{i=1}^{n} d_i}{n} \quad (2) \]

and \( D_E \) is the expected mean distance for the features given a random pattern:

\[ D_E = \frac{0.5}{\sqrt{n/A}} \quad (3) \]

In the previous equations, \( d_i \) equals the distance between feature \( i \) and its nearest feature, \( n \) corresponds to the total number of features and \( A \) is the total study area.

The \( z_{ANN} \)-score for the statistic is calculated as:

\[ z_{ANN} = \frac{D_O - D_E}{SE} \quad (4) \]

where:

\[ SE = \frac{0.26136}{\sqrt{n^2/A}} \quad (5) \]
APPENDIX B. Table of near-distance analysis in main polygon.

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>0-10</th>
<th>11-20</th>
<th>21-30</th>
<th>31-40</th>
<th>41-50</th>
<th>51-60</th>
<th>61-70</th>
<th>71-80</th>
<th>81-90</th>
<th>91-100</th>
<th>101-110</th>
<th>111-120</th>
<th>121-130</th>
<th>131-140</th>
<th>141-150</th>
<th>&gt;150</th>
</tr>
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<tbody>
<tr>
<td>FCR Features (n=196)</td>
<td>32</td>
<td>35</td>
<td>23</td>
<td>24</td>
<td>11</td>
<td>10</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>29</td>
</tr>
<tr>
<td>Masonry Structures (n=277)</td>
<td>13</td>
<td>22</td>
<td>17</td>
<td>14</td>
<td>4</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>153</td>
</tr>
<tr>
<td>Non-FCR Rock Pile (n=42)</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>Lithic Scatters (n=829)</td>
<td>7</td>
<td>18</td>
<td>26</td>
<td>24</td>
<td>35</td>
<td>33</td>
<td>31</td>
<td>27</td>
<td>20</td>
<td>30</td>
<td>25</td>
<td>21</td>
<td>18</td>
<td>26</td>
<td>21</td>
<td>467</td>
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