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Aboriginal Adaptations on the Colorado Plateau: A View from the Island-in-the-Sky, Canyonlands National Park, Utah

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ABORIGINAL ADAPTATIONS ON THE COLORADO PLATEAU: A VIEW FROM THE ISLAND-IN-THE-SKY, CANYONLANDS NATIONAL PARK, UTAH

By
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With contributions by
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ABSTRACT

This final report documents the results of archeological inventory, excavation, and analysis of prehistoric cultural resources within a 45-kilometer (28-mile) long corridor in the Island-in-the-Sky District of Canyonlands National Park, Utah. During three field seasons of survey, mapping, and excavation in 1983-1985, the research team recorded 32 artifact scatters, plotted 90,000 prehistoric artifacts and 250 historic items, completed 600 one-square-meter test pits, and conducted 10 block excavations. Block excavations at two locations in Gray's Pasture revealed a plant processing/hunting field camp (42SA16858) and a disturbed pithouse (42SA8506). Associated features and materials included a puddled clay-lined hearth, a slab-lined pit, a cached Mesa Verde Black-on-white olla, six additional restored ceramic vessels, chipped and ground stone tools, human remains, animal bone, and macrobotanical material. Radiometric determinations for these locations ranged from 1335 B.P. (corrected A.D. 690-795) to 940 B.P. (corrected A.D. 620-895). Radiometric dates for sites examined within the project area ranged from 2990 B.P. (corrected 1400-925 B.C.) to 120 B.P. (corrected A.D. 1655-1950). Research problems for this project included aboriginal patterns of land use, paleonutrition/diet/health, food storage, and caching strategies. Special emphasis was given to the investigation of artifact assemblage-diversity at varying spatial scales within surface artifact scatters.

ACKNOWLEDGMENTS

This final report represents the culmination of archeological research in the Island-in-the-Sky District of Canyonlands National Park, Utah, that began in 1979. This study represents the collective and concerted efforts of many people who dedicated much of their time, energy, and talents to the Canyonlands Archeological Research Project. Three seasons of pedestrian survey, instrument mapping, and test unit/block excavation were carried out under the direction of Susan Vetter (Midwest Archeological Center, National Park Service, and later the Department of Anthropology, University of Nebraska in Lincoln, Nebraska). Sue must be commended for her immeasurable contributions throughout the duration of this investigation, including 12-hour work days, consistent and rigorous field methods, initiative, and photographic mind. She also contributed very significantly to almost all of the computer-assisted work completed over the years. The three years of arduous fieldwork were accomplished by unusually compatible and capable field technicians, including: Steven Baumann, Jesslyn Brown, Tim Canaday, Judie Chrobak-Cox, Gary Crossan, Jim Dryer, Patrick Flanigan, Dean Flechs, Linda Haws, Nancy Hartman, William Isenberger, Marc Kodack, Christina Louise Koppel, Eric Manhart, Janet Mantel, Ben Munger, Kevin O'Connell, Lou Rankin, Denise Stocks, Sue Wacha, Laurie Walsh, Anne Wolley, and David Zeanah.

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Other National Park Service personnel that have provided invaluable assistance, advice, and support for this project include Pete Parry (former Superintendent of Arches and Canyonlands National Parks and Natural Bridges National Monument), Nick Eason (former Unit Manager for the Canyonlands Complex), Tom Wylie (former Head of Resource Management), Larry Thomas (Head of Resource Management), Jeff Connor (Resource Management), Kate Kitchell (Resource Management), Kevin Cheri (former Chief Ranger, Island-in-the-Sky District), Tom Cox, Ron Young, John Schuttenhelm, and Ward Tucker. Judie Chrobak-Cox shared a great deal of her knowledge with the crew regarding the archeology and ecology of the "Island's" environment. Lloyd Pierson (Dan O'Laurie Museum, Moab, Utah) enabled us to conduct examinations of osteological material and subsequent stable isotope and trace element analyses. Similarly, Winston Hurst (Edge-of-the-Cedars Museum, Blanding, Utah) contributed significantly to this osteological analysis.

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The following report reflects the combined efforts of a number of contributors. These contributors include: Susan Vetter (historical overview), Ralph Hartley (archeological overview), Jenny Waters and Alan Osborn (environmental information), Alan Osborn and Ralph Hartley (archeological research program and aboriginal land use), Susan Vetter (project definition, methodology, site descriptions), Jesslyn Brown (archeological features), Alan Osborn (artifactual remains and assemblage variability), Dean Wilson (ceramic classification), Jenny Waters (faunal assemblage), Linda Scott Cummings (pollen and macrobotanical remains), Tony Zalucha (charred wood), Galen Burgett (taphonomic analysis), Ralph Hartley (artifact displacememt), and Alan Osborn (conclusions).

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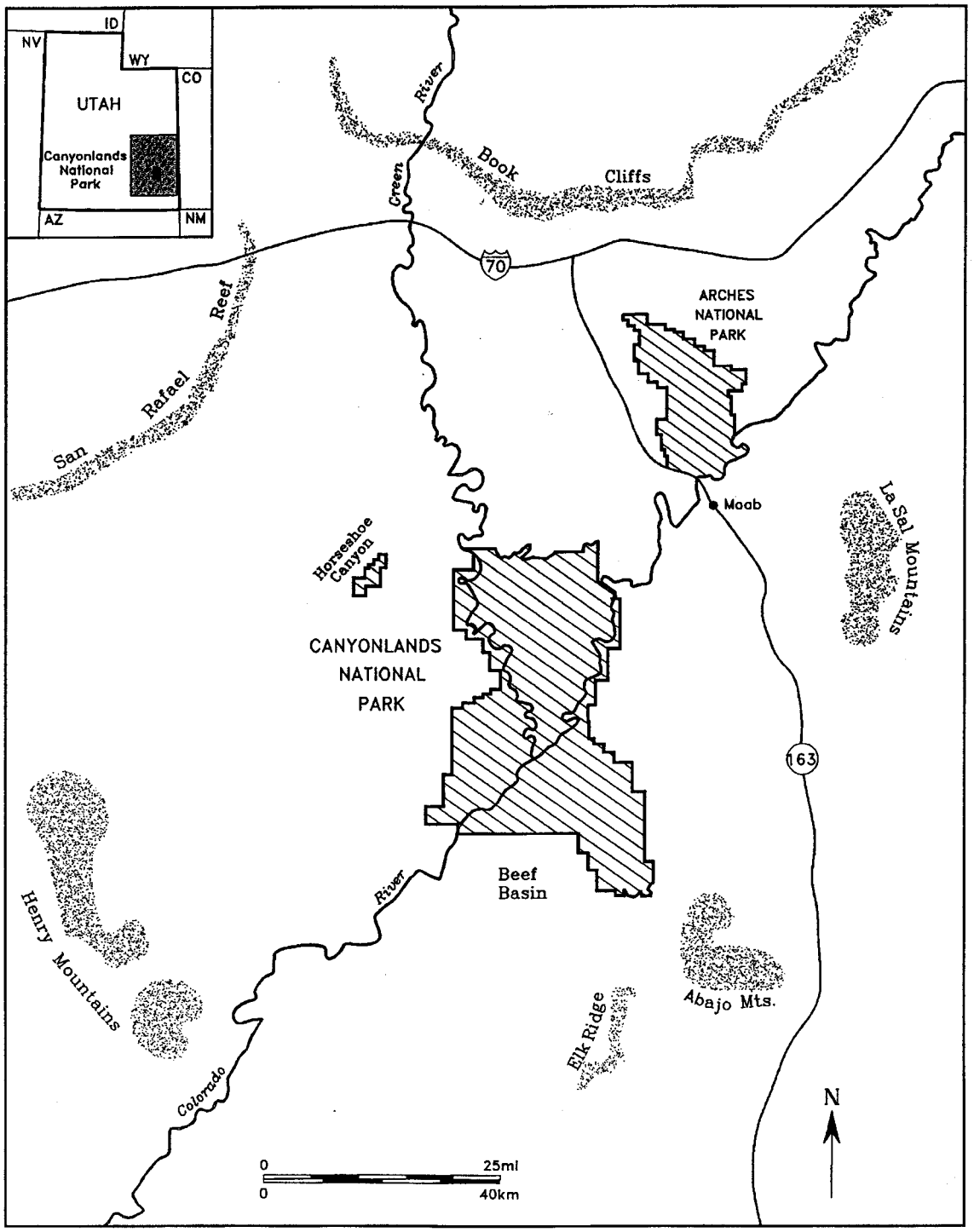


Figure 1. Location of Canyonlands National Park, Utah.

INTRODUCTION

BACKGROUND OF PROJECT

In 1982 Congress passed the Surface Transportation Assistance Act (sec. 126(a) P.L. 97-424) that established a coordinated Federal Lands Highway Program. Paving of the existing roadway on the Island-in-the-Sky District of Canyonlands National Park resulted from funding provided for by this act (Figure 1). The original narrow, winding dirt road on the Island-in-the-Sky (often referred to herein simply as, the Island) was initially established as an access route for sheep and cattle ranchers long before the park was established in 1964. Some alignment changes were made, and grades were changed to this roadway to comply with standards for modern vehicles.

Archeological survey of the original roadway was conducted in 1979 (Hartley 1980). Twenty-eight sites and seven isolated artifacts were recorded along this road corridor. In July of 1983 the Midwest Archeological Center was directed to begin archeological investigations along the first linear segment of the new road construction project. This work began August 1, and was forced to end November 11 due to inclement weather. The following spring, work resumed on April 16 and ended on July 27, 1984. These investigations completed evaluative work along the roadway up to near the "Wye," or intersection of road segments. The remaining portions of the roadway were examined beginning May 6, 1985. Soon thereafter, minor setbacks were experienced due to vandalism of excavation units and mapping stations. This second and final phase of archeological work ended October 25, 1985.

During the course of archeological fieldwork (1983-1985) on the Island an additional 83 acres from which borrow source materials were to be removed required survey and evaluative testing. Additional places to be disturbed by developments for park visitors and/or park personnel along this road were also examined during this period.

In 1984, a University of Nebraska anthropology field school surveyed 241 acres in three 100-meter-wide transects across the Island perpendicular to the existing road, under the Volunteers-in-Parks program (Osborn 1984). Although this activity in no way was associated with the road project, the archeological data retrieved from this work contributes substantially to our overall evaluation of prehistoric activities in the Island vicinity and is reported in conjunction with those resources investigated along the road right-of-way.

Archeological fieldwork involves the collection of materials that can be analyzed for the overall examination of the prehistoric use of the landscape. Although much artifact processing and initial laboratory work was begun during the 1983-1985 period, the analyses, ancillary analyses, tabulations, and report preparation could not be completed until funding for this work was allotted. In the spring of 1988 this funding was made available, and the writing and compilation of this report was begun.

We have been firmly convinced that productive archeological research must be guided by theoretical and methodological approaches that integrate current knowledge, answer pertinent questions, and generate new directions for future investigations. The research program that we initially designed to guide the investigations in National Park Service areas in southeastern Utah focused on prehistoric land use, food storage strategies, rock art function, and systemic links between diet, nutrition, and health. As we shall see, these four problem areas changed, and the overall focus of our studies shifted. However, the integrated nature of this research and its relationship with contemporary archeology and anthropology ultimately enabled us to investigate each problem. Prehistoric rock art function was investigated independently by Hartley and Baumann in the context of their graduate studies at the University of Nebraska-Lincoln. Certain aspects of prehistoric diet, nutrition, and health were investigated independently by the principal investigator, as well as by Ann Wolley as part of her graduate program at the University of Nebraska. And, our interest in monitoring and explaining archeological assemblage diversity was explored in several archeological projects in other parks and monuments within southern Utah. This problem was also investigated by Karen Kramer as a component of her graduate program at the University of New Mexico. We believe that our

archeological investigations in the Island-in-the-Sky District of Canyonlands National Park, Utah, have been broadened and strengthened by these independent, yet interrelated, research endeavors.

PREVIOUS ARCHEOLOGICAL INVESTIGATIONS

Southeastern Utah and southwestern Colorado have a history of archeological research that rivals any other area of similar size in North America. Interpretations of the prehistory and activities of human groups on this portion of the Colorado Plateau vary with the theoretical perspectives taken by the researchers, their backgrounds, and their goals. The prehistory of this area is usually described, however, by reference to chronological sequences and spatially limited characteristics. Most often, and in general, these units are designated within the context of Paleoindian, Archaic, and Formative (Fremont-Anasazi) developments. Syntheses of this culture history are well established and need not be reiterated here. This review will concern itself directly with evidence of prehistoric activities near the confluence of the Green and Colorado rivers. A complete review of documented field investigations in the Island-in-the-Sky District is provided in Appendix A.

Evidence of Paleoindian activities in the study area was first documented by the examination of surface-collected Folsom and Pinto projectile points, resulting in definitions of the "Moab Complex" (Hunt and Tanner 1960). Like these collections, much of the evidence for early human activities in the area is characterized by scattered finds of projectile points (Copeland and Fike 1988). Recently, however, Paleoindian sites have been investigated in detail near major river drainages. The Lime Ridge site overlooking the San Juan River, and the Montgomery site located on a terrace above the Green River contain Clovis and Folsom occupations, respectively (Davis 1985, 1989; Davis and Brown 1986). Evidence presented by Davis et al. (1985) suggests that due to the arid landscape of the Late Pleistocene, megafauna likely sought by Paleoindian hunters were concentrated along streams and other mesic habitats.

Archaic sites are documented throughout the Green and Colorado rivers drainage systems. Many of the interpretative scenarios resulted from stratified rockshelter excavations and open sites (e.g., Bungart 1990; Davis and Westfall 1988; Hunt 1990; Tipps 1984). Extended family and band level social groups likely employed a generalized hunter-gatherer pattern of subsistence and settlement during the Archaic period on the northern Colorado Plateau. Localities for residential occupation are presumed to have been dictated by the seasonal availability and abundance of food and water sources. The adaptational system likely fluctuated from a warm-season, residentially mobile adaptation to a cold-season, residentially sedentary-logistically mobile adaptation. Recently, the remains of a Late Archaic post-and-beam structure with multiple hearths and other features were examined in Lisbon Valley, about forty miles southwest of Moab, Utah (Davis and Westfall 1988).

The Formative period on the northern Colorado Plateau is generally considered a result of population increase, fostering greater employment of agriculture and the formation of villages. Anasazi and San Rafael Fremont cultural traditions, both considered marginal to the study area, are increasingly being recognized in site characteristics throughout the area. The presence of Basketmaker II-III sites throughout the Lisbon Valley area suggests substantial Anasazi activity during these periods (e.g., Black, Copeland, and Horvath 1982). A recently excavated Basketmaker II site in the valley revealed a large circular pithouse with a slab-lined hearth and miscellaneous other pits, as well as stone tools attributed to the period (Richens and Talbot 1989).

Pueblo period sites are well documented throughout the Canyonlands area, especially in the Needles District (e.g., Dominguez 1988; Griffin 1984; Osborn et al. 1986; Sharrock 1966; Tipps and Hewitt 1989). Archeological investigations in the Island-in-the-Sky District, far above the river channels, have also documented several Pueblo II-III sites with structural features characteristic of that period. Prominent on the Island is Aztec Butte, a Navajo formation that permits an expansive view of the Island (Figure 2). Ten small storage structures are situated in sandstone alcoves below the rim of the butte (42SA418, 42SA1681) (Gaunt and Eininger 1987; Gunnerson 1958; Hartley 1980; Sharrock 1966). A dry-laid rectangular room with a south-facing entryway is situated on the surface of the butte. A large alcove in Navajo sandstone overlooking Holeman Spring Basin (42SA1680) consists of one dry-laid large circular structure, two small rooms positioned against the rear wall, and eight subterranean storage cists. An anthropmorphic petroglyph with a bow drawn toward a mountain sheep is located toward the western edge of the alcove (see Gaunt and Eininger 1987; Hartley

1980). Several storage structures are found in small alcoves and ledges throughout the Island proper (e.g. 42SA414, 42SA1671, 42SA17588). Most are dry-laid/mudded in a semi-circular pattern with entryways (Figure 3).

Since 1949, numerous sites have been recorded along the road leading up to the Island-in-the-Sky District and Dead Horse Point (SR-313). These sites have been documented, for the most part, in response to land development activities, including road and state park development and geophysical exploration (e.g., Gunnerson 1958). Records filed with the Bureau of Land Management, Grand Resource Area Office, and the Division of State History, State of Utah, reveal several sites recorded within Sevenmile Canyon and along the general route to the Canyonlands National Park boundary. These sites range from lithic scatters with ceramics, ground stone, fire-cracked rock, and storage caches, to a large alcove with Basketmaker-styled pictographs. Most recently, Abajo Archeology resurveyed over eighteen miles of SR-313, documenting 41 sites, 37 of which required subsurface testing for evaluation of National Register of Historic Places criteria (Davis et al. 1989). Three of these sites underwent excavation in the summer of 1989 (Reed 1990). Results of these investigations suggest a broad range of forager-collector activities through time. Sites were attributed to Late Archaic through Numic occupations. Sites excavated by Alpine Archeological Consultants (Reed 1990) revealed a pithouse structure (42GR2211) attributed to the Muddy Creek phase (A.D. 700-1000) of the San Rafael Fremont. A component of a rockshelter (42GR2232) was attributed to the Bull Creek phase (A.D. 1000-12000), and a lithic/ceramic scatter was chronometrically dated to the mid-thirteenth century and attributed to Numic activities in the area.

This report was last revised in 1990. Some effort has been made to update aspects of the discussions and conclusions by referencing certain published studies that have appeared since then. The lack of time and funds precludes a complete update of the literature citations.

Artifact collections and field samples are stored under Canyonlands National Park accessions 247 and 248, which correspond to Midwest Archeological Center accessions 218 and 219. These collections were made during the 1983, 1984, and 1985 field seasons and are stored at the Midwest Archeological Center. Field notes and other records related to this project are also stored at the Midwest Archeological Center.

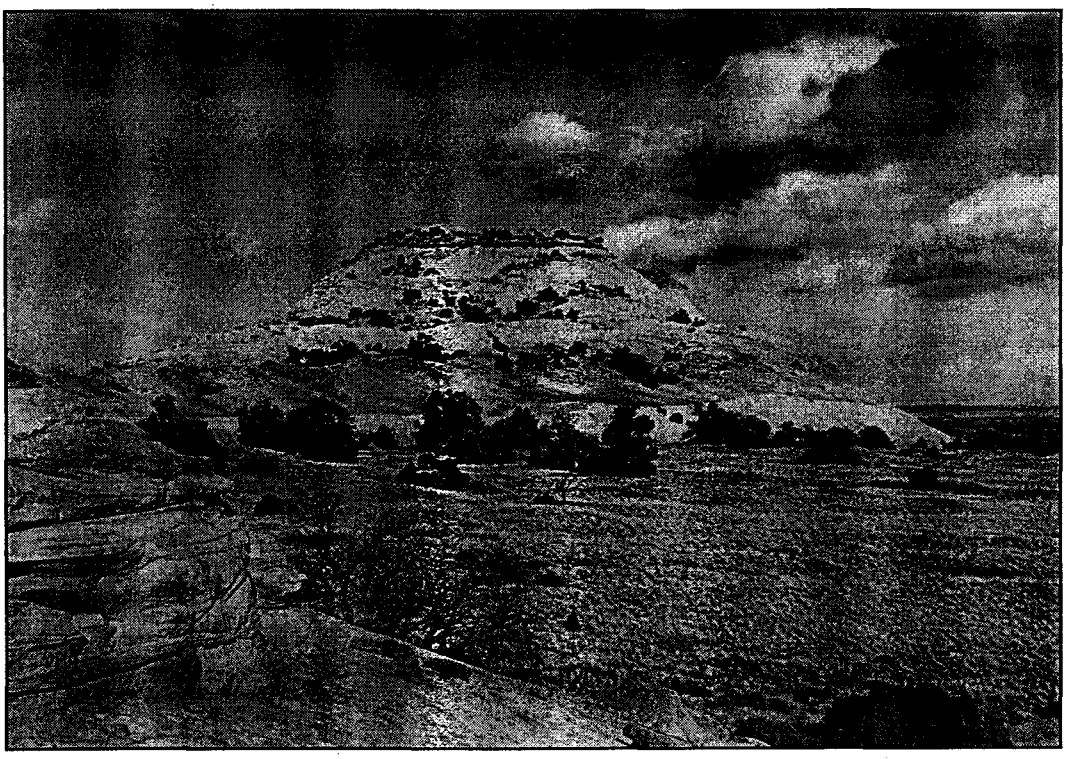


Figure 2. Aztec Butte viewed from 42SA16809.

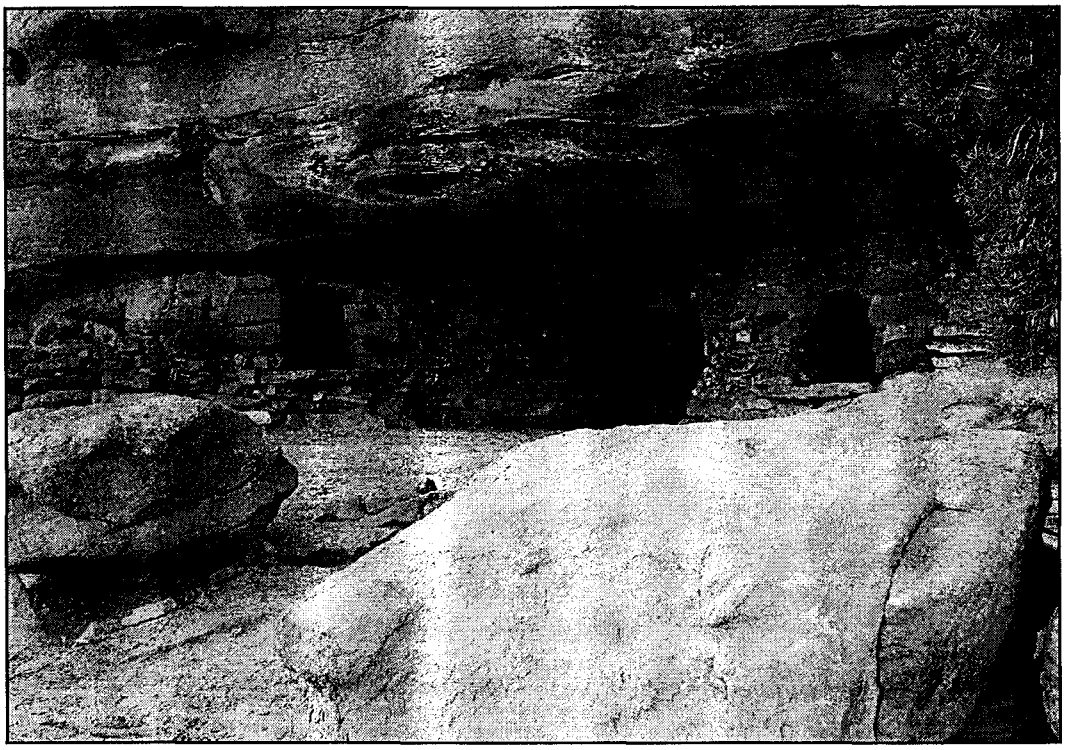


Figure 3. Masonry storage structures located at site 42SA414.

CANYONLANDS HISTORICAL OVERVIEW

EARLY EXPLORATION

The rugged topography and often inhospitable climate of southeast Utah delayed exploration of the area and limited the duration of treks into the canyons. Most often the area was viewed as an obstacle to be overcome. Captain John Macomb expressed the sentiments of many of these early white explorers when he led an expedition into the canyon country in 1859 and wrote from what is now the Needles District of Canyonlands National Park: "I cannot conceive of a more worthless and impractible region than the one we now find ourselves in." (Crampton 1983:60)

The Spanish were the first Europeans to enter the area. Although their excursions into southeast Utah were brief and were only made in the attempt to establish trading routes to the California settlements, the Spanish had entered the canyons by the early eighteenth century. Anasazi and Fremont groups supposedly abandoned the area sometime after A.D. 1300. Numic speaking groups had arrived from the Great Basin sometime after A.D. 1100 (Madsen 1975). By the 1730s, Spanish trade with Utes in the area was commonplace. Juan Maria de Rivera, in 1765, led the earliest recorded trading expedition to southeast Utah; he reached the Colorado River at present-day Moab (Pierson 1980:75). The most famous of these early Spanish expeditions was that of the Franciscan friars Francisco Atanasio Dominguez and Silvestre Velez de Escalante in 1776. The route today accepted as that chosen by Dominguez and Escalante passed east of what is now Canyonlands National Park, through Lisbon Valley, over the southwest spur of the La Sal Mountains, and into Spanish Valley to cross the Colorado River at Moab. The route then continued north and west to cross the Green River near present-day Green River, Utah (Peterson 1975:8). This route became known as the Spanish Trail and served as a trading route between the Spanish settlements in New Mexico and those in California.

A shortcut of this trail popularized in local legend crossed the Colorado River at the head of Cataract Canyon. The trail supposedly passed through what are now the Needles and Maze districts of Canyonlands National Park. The trail then entered the San Rafael Swell (Lindsay et al. 1984:73). Baker (1971:119) reported use of this trail by outlaws leading stolen cattle in the late nineteenth and early twentieth century. Little evidence for use of this trail by the Spanish exists other than the descriptive "Spanish Bottom" and "Spanish Steps" that name locations along the trail.

Few of the early Spanish explorers actually traveled into what is now Canyonlands National Park. Until the arrival of Mormon settlers in 1855, only fur trappers passed through the area. They perhaps followed the Spanish Trail, and from it explored the canyons. The most enigmatic of these early traders was Denis Julien. Julien may have been an associate of Antoine Roubidoux. Roubidoux established trading posts at Fort Uintah and Fort Uncompahgre in the 1830s. Julien had the habit of scratching his name and the date into rock faces. In and near what are today Canyonlands and Arches national parks and Natural Bridges National Monument, Julien left five "1836" dates alone (Mehls and Mehls 1986:45). One of these can be seen up Hell Roaring Canyon on the east side of the Green River, just north of the Island-in-the-Sky District. Frederick Dellenbaugh (1926:118), on the second J.W. Powell expedition down the Green and Colorado rivers, reported a Julien inscription from 1836 below the confluence of the two rivers. Another 1836 inscription just below the mouth of Cove Canyon (Stanton 1965:67) was inundated by the construction of the Glen Canyon Dam. Another 1836 and an 1837 inscription today lie beneath the waters of Lake Powell (Crampton 1964:15). Julien also left an 1844 inscription in Arches National Park (Pierson 1980:80).

As the silk hat replaced the beaver hat in the fashions of the 1840s, the fur trade declined. Government men supplanted the mountain men as explorers of the canyon country. The discovery of gold at Sutter's Mill in 1849 contributed to the determination of many to find a transcontinental link to California. This determination spawned the five great railroad surveys of 1853. Captain John W. Gunnison led one of these expeditions along the 39th Parallel into southeast Utah. Gunnison passed north of the canyonlands area as he moved west from what is now Grand Junction, Colorado, across the desert to ford the Green River at present-day Green River, Utah. John C. Fremont, in

1853, also led an expedition north of the canyonlands area. John N. Macomb led an expedition into canyon country in 1859. John Strong Newberry, America's foremost geologist at the time, accompanied Macomb. Macomb followed the old Spanish Trail into Utah. North of present-day Monticello, Macomb and Newberry left the Spanish Trail and headed southwest into the heart of what is now the Needles District of Canyonlands National Park. They followed Indian Creek, and observed the Colorado River from above. Baker (1933:10) contended that Macomb and Newberry mistook the convoluted meanders of the Colorado at the Loop for the confluence of the Green and Colorado rivers. Others, however, credit Macomb and Newberry as the first known white Americans to see the confluence of the Green and Colorado rivers (Peterson 1975:16-23).

The Civil War postponed any further exploration of the canyonlands area until 1869. In that year, and again in 1871, John Wesley Powell floated down the Green and Colorado rivers. By following the Green to its confluence with the Colorado and then floating down the Colorado, Powell passed through the heart of what is now Canyonlands National Park. Powell explored in what are now the Needles, Maze, and Island-in-the-Sky districts of Canyonlands National Park. On July 20, 1869, Powell and his brother, Captain Walter H. Powell, climbed to a point overlooking the confluence of the Green and Colorado rivers, below Grandview Point in what is now the Island-in-the-Sky District of Canyonlands National Park. As Powell stood between the two rivers and surveyed the land around him, he wrote:

> Wherever we look there is but a wilderness of rocks, deep gorges where the rivers are lost below cliffs and towers and pinnacles, and ten thousand strangely carved forms in every direction, and beyond them mountains blending with the clouds (Powell 1961:213).

While Powell explored from the waterways, Ferdinand V. Hayden and his surveying parties traversed the plateaus. Several of these parties penetrated southeastern Utah in the La Sals and Abajos. The Hayden survey parties extended only as far west as the Moab/Bluff longitude (Hayden 1876, 1878) and, thus, did not enter the area to become Canyonlands National Park.

EARLY USE OF THE CANYONLANDS AREA

Although several of these early explorers of southeastern Utah probably entered what is now the Island-in-the-Sky District, they did so only along the rivers. Historic use of the Island-in-the-Sky area probably did not begin until the 1880s. A party of Mormons first attempted to settle in the Moab Valley in 1855. They abandoned the so-called Elk Mountain Mission that same year under the pressure of Indian attacks (Tanner 1976:45-61). George and Silas Green entered the Moab Valley to winter their cattle in 1874-1875 (Tanner 1976:65). Crispen Taylor with his two nephews brought cattle into the valley in 1875 (Daughters of Utah Pioneers 1985:57). A prospecting party found Silas Green's body in 1877. George was never found (Tanner 1976:65-68). After the death of the Green brothers, only William Granstaff, for whom Negro Bill Canyon was named, and a French Canadian trapper lived in the Moab Valley at the old Elk Mountain Mission fort.

Gradually cattlemen entered the Moab Valley in the late 1870s and settled there. The Taylors returned with more cattle for the winter of 1880-1881. The Rays, Maxwells, and McCartys arrived in the fall of 1877, but soon moved on to La Sal. The Wilsons, Walter Moore, C.M. Van Buren, Fred Powell, John H. Shafer, and other families soon moved to the Moab area (Tanner 1976:68-71). The Utes had continued to farm in the valley. Oliver B. Huntington of the Elk Mountain Mission party of 1855 noted that the Utes had planted ten acres of corn, melons, squashes, and pumpkins (in Tanner 1976:54). None of these early settlers of Moab used the Island-in-the-Sky or White Rim areas as grazing for their cattle. In those early days, they did not need to enter the forbidding country of broken rock between the two rivers to find grazing lands; they could find plenty of good grazing closer to home.

In the stark landscape of the canyonlands, geologic features dominate the eye and imagination of the viewer. Much about the history of the Canyonlands area and of the Island-in-the-Sky itself is revealed by the names. The terms "White Rim" and "Upheaval Dome" refer to geologic features of the area. Upheaval Dome is either a collapsed salt dome (Joesting and Plouff 1958) or the impact crater from a gargantuan meteorite (Boone and Albritton 1938). These geologic features did not receive their names from the geologists. Instead, local people used these descriptive terms for the area.

Geologists later adopted the terms. The White Rim does indeed appear to be a white rim around the base of the Island mesa. It separates the Island mesa from the deeply incised canyons that empty into the Green and Colorado rivers. Kenny Allred (1985), whose family grazed cattle and sheep on the Island and the White Rim early in this century, had always known the area as the White Rim. Art Murry (Behrendt 1985:64) also recalled a trip along the White Rim in 1914 or 1915. In 1927, geologists (Baker et al. 1927:794) acknowledged that the notable tongue of white sandstone atop the Cutler Formation that made a pronounced bench was known to local residents as the White Rim. The use of the local term "White Rim" to refer to this sandstone became so common that Baker and Reeside (1929:1424-1425) advocated that this sandstone tongue should no longer be known as the De Chelly but as the White Rim Member of the Cutler Formation.

As more settlers moved into the Moab Valley and the surrounding area, a few ventured into the land between the rivers. The one who first gave Grand View Point its name did not claim the distinction. After all, what credit did he deserve for simply describing what he saw? The first to claim the Island mesa and the White Rim for his cattle was probably Preston Nutter. Nutter was one of the biggest cattlemen in Utah from the late 1800s until his death in 1936. Nutter ranged cattle from the Uintah Basin east of the Wasatch Mountains to the Arizona Strip in Utah. From 1886-1893, Nutter's range extended from the Book Cliffs south to the confluence of the Green and Colorado rivers. In 1893, Nutter sold his interest in this area in order to lease all the land that drained into the Duchesne River from the west (665,000 acres). Nutter also retained his interests in the Arizona Strip (Price and Darby 1964:237-242). Sheire (1972:23), in his study of the history of cattle grazing in Canyonlands National Park, questioned whether Nutter ever extended his range as far south as the confluence area. No record exists of Nutter's use of the present Island-in-the-Sky area.

GRAZING IN THE ISLAND-IN-THE-SKY AREA

No documented use of the Island area occurred until the 1890s. Otho Murphy, in an interview with James Sheire (in Sheire 1972:24), claimed that Deb Taylor (Adelbert Taylor, nephew of Crispen Taylor and brother of Arthur Taylor [Daughters of Utah Pioneers 1985:56-57,61]) moved cattle into the area of Big Flat, north of the Island-in-the-Sky, and into Taylor Canyon, on the west side of the Island-in-the-Sky on the White Rim (Figure 28, page 90). Murphy also claimed that his family moved cattle onto the Island at about the same time. Gray's Pasture on the Island-in-the-Sky received its name from one of Deb Taylor's horses, a big gray stallion that grazed there (Allred 1985 and Behrendt 1985:36). J.D. Dillard (quoted in Behrendt 1985:21), a past district manager for the Grazing Service, remembered that his friend Bill Snyder scouted out the Island and Dead Horse Point areas for new grazing lands for his cattle. Snyder left some horses penned out beyond the Neck, on a point above the Colorado. When Snyder returned, the horses had choked to death and "Dead Horse Point" would not be forgotten.

By the turn of the century, other cattlemen, including Al Holeman, Reardon, and Patterson, ran cattle in the area. These early cattlemen in the Island area confined their use to the Big Flat and Gray's Pasture areas on the mesa top and to Taylor Canyon on the White Rim (Sheire 1972:24). They drove their cattle into Taylor Canyon down what is now the Alcove Spring hiking trail (Allred 1985). The head of this trail on the mesa is site 42SA8512.

How many cattle these men brought to the Island area and how much of the year the cattle remained is not known. Some used the area only as winter range; they drove their cattle to the La Sal Mountains in the summer. Others, however, attempted to use the area year-round. Big Flat and Gray's Pasture served as the summer range. The lower elevations of Taylor Canyon and the Green River side of the White Rim provided winter range. Taylor and Holeman drifted their cattle down Taylor Canyon to the Green River and then along the river bottom and into the area of Upheaval Dome. By 1914 this area was locally known as the Taylor-Holeman range (Sheire 1972:24). The names for Taylor Canyon and Holeman Springs Basin on the White Rim south of Upheaval Dome preserve today a record of the early use of the area by these men.

The east side of the White Rim above the Colorado River was not used by cattlemen until later. Sometime after 1900, John Jackson supposedly crossed the Colorado with his cattle from his range in the Dry Valley - Hatch Point - Hart Draw region on the east side of the river to Potash on the west. From Potash, Jackson

drifted his cattle as far south as Monument Basin, below the White Rim. In 1914 or 1915, the Shafer family bought Jackson's range. John and brother Frank Shafer built a stock trail from the Neck (location of site 42SA8502) on the Island-in-the-Sky down to the White Rim (Sheire 1972:24). The Shafer Trail was later improved into a jeep road after World War II and today serves as the access road within Canyonlands National Park to the White Rim.

In 1914 the Murphy brothers constructed a stock trail from Murphy Point (location of site 42SA8500) on the Island mesa to Murphy Hogback on the White Rim. Otho Murphy claimed that he and his brothers built the trail to provide access for their 100-150 cows to the grazing lands south of Murphy Hogback (Davis 1978:B1). Otho Murphy, in a 1972 interview with James Sheire, listed the size of the Murphy brothers' first herd as only 25 and claimed that their range extended from Murphy Hogback, on the west side of the White Rim, to the confluence of the Green and Colorado and back north to Monument Basin, on the east side of the White Rim. The Taylors controlled the area north of the Murphys' range on the west. The Shafers controlled the area on the east of the Murphys' range above Monument Basin. The Murphy brothers claimed the White Crack area as their range, according to Otho Murphy (in Sheire 1972:24). Kenny Allred, whose family ran cattle in the 1920s and 1930s on the White Rim and Island-in-the-Sky, in a 1985 interview, recalled being told as a boy that the Murphys did not last more than a winter or two with their cattle at White Crack. By 1917, the Murphys were bankrupt and were forced to sell their cattle and end their brief stay at White Crack (Sheire 1972:25).

As more families entered the Island and White Rim areas with their livestock, the record of use of the Island and White Rim areas remained unclear. Both Mehls and Mehls (1986:132) and Sheire (1972:25) mentioned that the Loveridges ran large numbers of sheep on the Island-in-the-Sky after 1900. What range they claimed on the Island mesa or on or below the White Rim is not known. Southeast Utah avoided the bloody "sheep wars" that plagued many other areas. The poor quality of much of the grazing area and the deeply incised canyons that separated much of the good grazing patches limited the size of cattle herds. Ranchers had to adapt to changing conditions. In particularly dry years they may have had to drive their cattle all the way down to the rivers to find water. Sheep could often survive in conditions too harsh for cattle. For this reason, many of the cattlemen in the canyonlands area also ran sheep. Kenny Allred (1985) said that his family ran sheep and cattle in the 1920s and 1930s. In fact, Allred (1985) claimed that in 1932 his family sold their cattle to Art Murry and began to graze only sheep in the area. They grazed the sheep for only one year. Gray's Pasture became too dry in the summer to keep the sheep there (Allred 1985).

These early stockmen in the area between the rivers did not engage in the range wars over the public domain that raged in other areas. They did have disagreements, but each seemed to be solved simply by the threat of violence (see Behrendt 1986:65 for a stand-off between Murry the cattleman and Bill Tibbetts the sheepman). Neither did these stockmen attempt to acquire these grazing lands through the Stockraising Homestead Act of 1916. This act increased the size of the homestead to 640 acres for grazing of livestock in those arid western areas where farming could not support the homesteader (Foss 1960:27). Kenny Allred's family (Allred 1985) attempted to homestead 640 acres in the mid 1920s in the Island and Horsethief Point area, but they never secured the homestead patent by establishing a residence on their claim.

By the 1920s, the Murphys had abandoned the cattle business in the land between the rivers. The Taylors remained in the area, as did the Allred family. The Allred family included Amy Moore Allred and her two brothers Bill and Eph Moore, Amy Allred's son Bill Tibbetts from a previous marriage, and her son Ken Allred. By this time, the Allreds and Moores ran both sheep and cattle in the Maze and across the Green River on the White Rim and the Island mesa. Art Murry entered the scene about 1930. Murry eventually developed Horsethief Ranch on Horsethief Point north of Taylor Canyon. In the early thirties Murry claimed the following as his range: "My range was Gray's Pasture, the Big Flats, White Rim out on the point, to where one part of it goes to the Colorado, the other to the Green, and the bottoms including Upheaval. I stayed on the Green River side" (in Behrendt 1985:66). Murry trailed his cattle from top to bottom. He and his cattle spent the winter on the White Rim and on the bottoms. In summer Murry moved his cattle up to Big Flat and Gray's Pasture or to summer range in Colorado. Murry never had more than 450 cattle on his range (interview with Art Murry in Behrendt 1985:66-72).

At the time that Murry ran cattle on the Green River side of the Island-in-the-Sky, Roy Johnson and Roy Holyoak also had cattle in the area. Between 1929 and 1937 their outfit ran between 250 and 500 cattle. Most of the Holyoak and Johnson range lay on the east side of the Island mesa, from the Shafer Trail south. On the west, the range reached only as far as Murphy Hogback. Holyoak and Johnson used the present park area only for winter grazing. In the summer they trailed their cattle up to Big Flat and then on to the La Sal Mountains (interview with Roy Holyoak in Sheire 1972:25-26).

Winter grazing on the White Rim and in the canyons below the rim required that the cowboys move with their cattle. The cattle had to be moved from one grazing area to another and from one rock tank to another. If the tanks dried up, the cowboys had to trail their cattle to the river, where quicksand would threaten their cattle. Each fall and spring the cowboys would use the well-known trails that led down from the Island mesa to the White Rim. Most of these trails are preserved as hiking trails in the park today. The Wingate Formation offer s few breaks in its scarp to allow passage from the Island mesa to the White Rim. An archeological site rests at the top of each of these trails. The Alcove Spring Trail was used to run cattle into Taylor Canyon or from the canyon onto the Island top. The Murphy Trail led from Murphy Point on the mesa to Murphy Hogback on the White Rim. Horsethief Trail on the west and Shafer Trail on the east of the mesa were later developed into roads and are today used for access to the White Rim jeep trail.

White Crack, at the southernmost tip of the White Rim, offered a trail from the White Rim to the canyons below. Access to the Green River was not possible from the White Rim from Potato Bottom to White Crack. Art Murry and Holyoak and Johnson probably also used the trail at White Crack that provided access to the canyons below the White Rim. Kenny Allred (1985) and his family used the trail for their cattle, as did the Murphys. Below the White Rim, a cowboy could trail his livestock along the contour at the upper ends of the canyons that drain into the Green River and move south into a wide grassland of over 3000 acres just north of the confluence of the Green and Colorado rivers. As long as snows provided water, the cattle could graze for the winter there.

The claims of ranchers on the grazing areas of the land between the two rivers changed dramatically in 1934, when Congress passed the Taylor Grazing Act. The purpose of this legislation as set forth in its preamble was:

> To stop injury to the public grazing lands by preventing overgrazing and soil deterioration, to provide for their orderly use, improvement, and development, to stabilize the livestock industry dependent upon the public range, and for other purposes. (Quoted in Foss 1960:59)

The Secretary of Interior was authorized to establish grazing districts on lands which were, in his opinion, suitable for grazing. These grazing districts occupied 142,000,000 acres. The present park area between the two rivers became part of Grand Grazing District Number 9, The Big Flats Unit. Art Murry never acknowledged the new bureaucracy. At first, he received no permit for grazing lands within the district. Later Murry received a permit for 250 cattle, but lost it within two years (Behrendt 1985:67). Murry also never filed for a 640-acre homestead; consequently, he had no claim to any of the lands he had lived and worked on for years. Murry grazed his cattle illegally for years, but was finally cut off by the newly formed Bureau of Land Management (BLM). The BLM replaced the Grazing Service as custodian of the public domain in 1946. The BLM issued Murry a permit for only 16 head of cattle (Muriel Murry interview in Behrendt 1985:90). Murry sold Horsethief Ranch to Kenny Allred in 1951. Under the Small Homestead Act, Kenny Allred was able to purchase five acres of land where the ranch buildings were. He leased two school sections from the state and was able to run a small herd of cattle (Allred 1985). After Art Murry, the owners of Horsethief Ranch would not play a major role in the history of grazing within the present park area.

One sheepman had a large impact on the character of the east side of the present Island-in-the-Sky District. Howard Lathrop from Montrose, Colorado, had wintered his sheep on Big Flat, north of the present park, in 1933-1934. After passage of the Taylor Grazing Act in 1934, Lathrop did not receive another permit for grazing on the land between the rivers until 1938, when he again received a permit for winter grazing of 1150

sheep at Big Flat. The Grazing Service adjusted his allotment for the next winter and assigned him land on the White Rim and below, and in Gray's Pasture. Lathrop's winter grazing permit extended for five months and stabilized at 2000 sheep. His permit allotted him a 35-mile stretch on the east side of the White Rim. Lathrop quickly began to make improvements to his range. He hauled cement by boat down the Colorado, then used mules to bring it from the river up to the White Rim. The canyon Lathrop used for access to the river still bears his name. Lathrop used the cement to wall up edges of slickrock pockets in the White Rim sandstone. These served as water tanks for his sheep. Lathrop also built corrals. Many of Lathrop's improvements can still be seen today; many of his tanks still hold water and are now watering holes for bighorn sheep. Lathrop's most significant contribution to what is now Canyonlands National Park was his construction of a trail from his allotment in Gray's Pasture down to his allotment on the White Rim. Lathrop blasted a narrow foot trail down the precipitous benches of the Kayenta and Wingate sandstones into the talus of the Chinle and Moenkopi formations and on to the White Rim (Lathrop 1972:160-178). This trail serves as a hiking trail in the park today. The storage granary that Lathrop placed at the top of the trail can still be seen in Gray's Pasture.

Lathrop sold his sheep in 1951 but retained his permits (Lathrop 1972:333). A 1953 map of Grand Grazing District 9 (Lathrop 1972:frontispiece) showed the area permitted to Lathrop as a section of Long Canyon north of Dead Horse Point and the White Rim from Shafer Trail south to White Crack. The Allies Brothers and James G. Brown split the Island top between them. The Allies also controlled the west side of the White Rim. Both of these outfits ran cattle on their allotments.

The grazing permit records at the Bureau of Land Management Grand Resource Area office (BLM,GRA) in Moab reveal a succession of permit holders. Although Howard Lathrop sold his sheep in 1951, he retained his grazing permit and leased it to other ranchers. Martin Etchart held the Lathrop permit in 1960, according to a Bureau of Land Management (1936-1938) map from that year. In 1964 Etchart continued to lease Lathrop's permit. The permit allowed Etchart to run 1200 sheep and a couple of horses from December until April (Jense 1964). By 1972 Tad Paxton had the White Rim Allotment permit. He was allowed just over 1000 sheep on the allotment (National Park Service 1972). In 1964, Fougnier and Giles of Loma, Colorado, held the permit for Gray's Pasture, Taylor Canyon, and along the Upheaval Dome Road. They used this area for winter grazing of sheep. The Allies brothers continued to graze sheep on the west side of the White Rim (Jense 1964). By 1972, Ina Young and Fournier and Giles had split the Gray's Pasture allotment. Young held a permit for winter grazing of cattle. Ina Young also held a permit for the grazing of cattle in Big Flat and in Red Sea Flats. Emery Holman grazed sheep on the west side of the White Rim. Karl Tangren grazed cattle at the base of Shafer Trail (National Park Service 1972). All of these permits specified use from December until the spring. The AUMs per permit was decreased through the sixties. As the uranium boom of the 1950s spurred road development, these later permit holders could truck their animals in and out of the area.

Public Law 88-590 of September 12, 1964, established Canyonlands National Park "... in order to preserve an area in the State of Utah possessing superlative scenic, scientific, and archeological features for the inspiration, benefit, and use of the public ..." Those who held grazing permits within the park at the time of its establishment had those permits extended until June 30, 1975 (National Park Service 1977:7). The importance of the area between the two rivers for winter grazing of cattle had decreased over the years. In fact, only 23 cattle officially grazed between the two rivers in 1962. Over 5,600 sheep were on permit in the area in that same year (Edminister 1962:126). In 1975, grazing ceased in most of the Island-in-the-Sky District, although grazing continued until 1983 in a small portion of the district. Public Law 92-154 extended the north boundary of the Island-in-the-Sky District from Red Sea Flats approximately 3.2 kilometers north along the north rim of Taylor Canyon, across the mesa, and down to include the Middle Fork of Shafer Canyon. Grazing in this addition continued until 1983. At that time, all grazing permits within the Island-in-the-Sky District expired.

THE ROLE OF THE CIVILIAN CONSERVATION CORPS

The Roosevelt Administration created the Civilian Conservation Corps (CCC) in 1933. The activities of the CCC would have a direct impact on the Island-in-the-Sky area and an unknown impact on certain of its archeological sites. CCC crews worked under

the Departments of Agriculture and Interior. Several CCC camps were attached to the Division of Grazing under the Department of the Interior. The Division of Grazing served as the predecessor to the Bureau of Land Management. The Division of Grazing CCC camps worked on water development tasks such as drilling wells and piping springs (Salmond 1967).

Moab received one of these camps in 1935. The camp was constructed at Dalton Wells, north of Moab, and was occupied until 1941. The Dalton Wells camp was designated DG-32 (for Division of Grazing camp 32). The Archives Branch of the Denver Federal Archives and Records Center houses the records of these Division of Grazing camps in Record Group 49.

What impact did the activities of the CCC have on the Island-in-the-Sky? The most obvious are still evident. The CCC added piping and water troughs to the Neck and to Cabin Spring below 42SA8502. They then constructed a stock trail to these springs (Bureau of Land Management 1936-1938). At Willow Seep, the CCC tried to improve the water flow by blasting it. They also installed piping and a water trough there. 42SA415 is located at Willow Seep. The CCC constructed a small reservoir in Red Sea Flat and a larger one in Big Flat. They also constructed concrete dams on slickrock exposures in Gray's Pasture in an attempt to create holding ponds. They may also have been responsible for the etching of channels in the slickrock leading into a large pothole at the present picnic area on the Grand View Point Road (Bureau of Land Management 1936-1938).

Perhaps the most disturbing aspect and the least well documented of the CCC activities on the Island-in-the-Sky is the road building. No roads, only wagon trails led the way to the Island-in-the-Sky in the late 1930s. Project #8-23 was called the Gray's Pasture Road. Under this project, the CCC crews completed 32 miles of improved dirt road. In the construction of this road, the crew moved 40,841 cubic yards of earth, excavated 1,187 cubic yards of rock, installed 26 rock and cedar post culverts, constructed two large rock dips, and cleared 52 acres of brush (Bureau of Land Management 1936-1938). The record is unclear as to where this road started and where it ended. The name clearly reveals that it at least entered Gray's Pasture. It may have ended at the start of Gray's Pasture, where it would have provided access to the grasslands there. The road crossed Big Flat, Red Sea Flat, and the Neck. As will be discussed later, 42SA8506, at the south end of Gray's Pasture, seemed to have been disturbed prehistorically and may have been disturbed again historically. Immediately east of the site area is a saddle between the dunes that leads to a depression. The imagination does not have to tax its powers to see that this saddle resembles an old road cut that may have led to a borrow area. If, in fact, the CCC road building extended through Gray's Pasture, 42SA8506 may have been severely disturbed by these activities.

MINERAL DEVELOPMENT

Oil and Gas Exploration

Mineral development in the Moab area began not long after ranchers introduced the first livestock to the area. In the 1890s some of the first oil wells in the area were drilled in the Green River Desert, 40 miles northwest of Moab. The first well was drilled along the San Juan River in 1907. Both of these areas saw a number of wells drilled until about 1914. The Green River Desert wells never yielded more than a trace of oil. Several of the wells along the San Juan River produced some oil, and continued to produce for many years. Another well was drilled a few miles southwest of Cisco, Utah, at the turn of the century. The area immediately around Moab did not receive the attention of the oil men until the 1920s (Baker 1933:80).

In 1918 and 1919 a well was drilled on the Salt Valley anticline, just west of what is today Arches National Park. The Moab Valley became the site for wells in 1920. The most famous well drilled near Moab was the Frank Shafer No. 1. This well lay 15 miles downriver from Moab. Oil and gas gushed from this well in 1925. The ensuing fire burned the rig and suspended drilling. Drilling later continued at this well, but the operators were never successful in their attempts to recover oil from promising rock beds. The strike at Frank Shafer No. 1 encouraged the drilling of other wells along the Colorado (Baker 1933:81). By the early 1930s, most drilling had been suspended in the Moab area.

From 1924 until 1955, 11 exploratory wells were drilled in the Cane Creek and Shafer anticlines, and in Big Flat. The Cane Creek and Shafer anticlines intersected the Colorado downriver from Moab. The

Frank Shafer No. 1 well was drilled in the Cane Creek anticline (Baker 1933:Plate 2). The Big Flat area lies just a couple of miles north of the present Island-in-the-Sky District boundary. The first well was drilled in Big Flat in 1948. Other wells were drilled in the Big Flat area in the early 1950s. All of these wells were abandoned (Carlton 1958:254- 255). The development of commercial oil and gas deposits in Big Flat in the 1950s resulted in the improvement of Island top roads. Seismic lines were run in the hope of identifying other favorable oil and gas areas. Scars from these lines may still be seen today in many areas of the Island-in-the-Sky.

In 1957 Pure Oil Company made the first successful wildcat oil strike at Big Flat No. 1. Other wells followed (Papulak 1963:457). The first well to be drilled within the boundaries of what is now the Island-in-the-Sky District was the British American Oil #1 Federal - Ormsby in 1958. British American drilled this well in Red Sea Flats, which lies just south of the present Island-in-the-Sky north boundary. Shell Oil drilled #1 Murphy Range in 1961 along the Grandview Point Road south of its intersection with the Upheaval Dome Road. Pan American Petroleum drilled its #1 Unit near the Green River Overlook near what is now the campground for the Island district in 1962. The Husky #1 Government well was drilled in 1963 along the Upheaval Dome Road. Each of these wells was plugged and abandoned after they failed to yield more than trace amounts of oil and/or gas (Heylmun et al. 1965:158-160).

Each of the above-listed wells, with the exception of the Husky #1 Government well, has been identified on a map of historic features stored at the Canyonlands National Park headquarters (National Park Service n.d.). A map of existing development in the Assessment of Alternatives in the General Management Plan for Canyonlands National Park (National Park Service 1977:28) identified the oil well sites in Red Sea Flat and along the Grandview Point Road. Both of these maps omitted some of the wells known to have been drilled within the present park boundaries. These maps, however, included an oil well site located at White Crack that was not identified in any of the drilling records. Papulak (1963) did not discuss the drilling of a well on the White Rim when he discussed the oil and gas occurrences within the proposed Canyonlands National Park boundaries. Neither Baker (1933) nor Prommel (1935) discussed any drilling on the White Rim before the early 1930s. Oil drilling essentially ceased in the Canyonlands area from the early 1930s until the late 1940s. Hansen and Scoville's (1955) compilation of the drilling records for oil and gas in Utah from the drilling of the first well in Utah in 1891 until 1954 did not list any drilling in the present Island-in-the-Sky District. A well at White Crack was not noted in the compilation by Heylmun and others (1963) of oil and gas drilling records in Utah from 1954 to 1963. If the drillers of the White Crack site never registered their actions on the public domain with the proper authorities, the compilers would not have have located the well. Unless such unusual circumstances occurred, the White Crack drillhole could not have been an abandoned oil well and probably was a stratigraphic test drilled by uranium miners.

Uranium miners in the 1950s needed an understanding of the stratigraphy of deposits. Drilling is a well-established prospecting technique. Charlie Steen, perhaps the most famous "rags to riches" story from the uranium boom, was drilling in his Big Indian claim when he recovered the drilling cores that were to signal the location of one the largest uranium deposits (Newell 1976:15). When the U.S. Geological Survey began exploration for uranium-bearing deposits on behalf of the Atomic Energy Commission in the late 1940s, the Geological Survey drilled extensively. First the Geological Survey drilled holes spaced at intervals of 1,000 feet. With the geologic information recovered from these drilling cores, the Geological Survey decreased the intervals to 100 to 300 feet to find ore deposits. In the final stage, the Geological Survey attempted to define the limits of the ore deposits by drilling at intervals of from 50 to 100 feet (Weir 1952:15-17). Such investigatory drilling took place on the Island-in-the-Sky. Exploratory cores from the drilling enterprises of uranium seekers on Murphy Point lie on the surface next to the test hole. They could use the cores to identify uranium ore deposits or favorable stratigraphic traps for uranium.

Uranium Exploration

Early Searches for Uranium Ores. The mining of uranium ores in the Moab area began at the same time as oil and gas exploration. As early as 1898, the occurrence of uranium-vanadium ores was reported in southwestern Colorado. Boutwell (1905) described the uranium-vanadium-copper bearing ores in an area north of

the La Sal Mountains. By the early 1900s vanadium-uranium ore had been discovered on Brumley Ridge southeast of Moab (Chenoweth 1975:253). Albert M. Rogers opened his Blue Goose mine there in 1908 (Mehls and Mehls 1986:165).

The early mining of uranium-bearing ores served primarily to provide scientists with samples of radioactive elements. In 1898 Marie and Pierre Curie discovered the element radium in uranium-bearing ore. Madame Curie, reportedly, encouraged two Frenchmen to inspect the uranium resources of the Colorado Plateau. Messrs. Pouilot and Voilique built and equipped a uranium concentrating plant on the Dolores River in San Miguel County, Colorado. Madame Curie named the uranium ore produced in the area "carnotite" after A. Carnot, a French physicist (Tanner 1976:212).

Mining for carnotite at the beginning of this century focused on the recovery of radium and vanadium. Radium was beginning to be used in research for the treatment of cancer. Vanadium assumed importance with the development of new steel alloys that required vanadium as a hardening agent. Uranium had limited uses at this time as a coloring ingredient for ceramics and ink dyes, in the manufacture of glass and pottery, and for experimentation in photography. The first radioactive mineral boom had begun.

In March and May of 1912, 18 claims on uranium-bearing ores were staked in San Juan County. The Pack Creek and Church Rock areas and Dry Valley were the sites of early claims. Prospectors staked about eight claims a month in 1912 and 1913. This figure jumped to 139 claims in the months of January and February 1914 (Weber 1979:171). Individual prospectors did not control this boom. Large companies entered the area. In 1913, the Vanadium Ores Mining Company purchased mines at Sayers, on La Sal Creek in southwestern Colorado. Standard Chemical Company established its base of operation farther south and became the other large producer of radioactive materials at this time (Mehls and Mehls 1986:165). The Grand Valley Times in Moab noted the emergence of the mining industry in its February 13, 1914, edition: "That the interest of the mining world is centering on the rare metals fields uranium and vanadium of this section is evidenced ... by the arrival of uranium experts and buyers."

The price of refined vanadium doubled between 1912 and 1917. The increased wartime demand for vanadium steel fueled the price rise. Radium was used to illuminate watch faces, gunsights, compasses, and gauges. The demand for uranium-bearing ores continued after the war. In 1918, the United States Metals Reduction Company built a plant in Utah just southwest of Gateway, Colorado. Standard Chemical Company employed nearly 200 workers on claims in southwestern Colorado and in southeastern Utah (Tanner 1976:216).

The postwar optimism soon ended with the depression of 1921 and the discovery of radioactive pitchblende deposits in the Belgian Congo. With the development of these deposits, the mines and mills in southeast Utah soon closed. Union Carbide delivered the final blow to the uranium ore industry when, through its subsidiary Vanadium Corporation of America, it attempted to gain a monopoly of what remained of the carnotite business in the late 1920s. These efforts led to a number of antitrust suits, augmented by the Great Depression, that ended carnotite production on the Colorado Plateau (Mehls and Mehls 1986:166).

A second vanadium boom began in the late 1930s. The outbreak of World War II once again increased the demand for vanadium in military production. The urgency of wartime encouraged the federal government to spur production. In 1942, the government formed the Metals Reserve Company, began an ore purchasing program, and increased the base price paid for vanadium. Processing mills for vanadium were erected in Monticello and near Blanding, Utah (Chenoweth 1975:253). Local production of vanadium doubled between 1942 and 1943. After such success, the War Production Board decided to curb production. By the end of February 1944, the processing plants at Monticello, Blanding, Gateway, and Durango were closed. The uranium produced as a by-product of the vanadium refinement was used in the Manhattan Project's development of the atom bomb (Weber 1979:173). The vanadium bust came in 1944, but the uranium boom would soon resound.

The Uranium Boom of the 1950s. The atomic power unleashed with the dropping of bombs on Hiroshima and Nagasaki in 1945 announced the dawn of the nuclear age. Uranium then became the most strategically important mineral in the world. The strong market for vanadium and the weak demand for uranium had led local miners to ignore uranium. Some uranium

had been reprocessed from low-grade tailings at vanadium mills in Utah and Colorado. These covert activities supplied uranium to the Manhattan Project (Tanner 1976:218).

After the war, the federal government wavered in its commitment to uranium production. At first, the efforts of the federal government focused on devising methods to control the spread of nuclear power and to protect the nation's monopoly on nuclear power. As tensions escalated between the United States and the Soviet Union, the government encouraged the production of nuclear weapons and created the Atomic Energy Commission (AEC). The AEC promoted the production of uranium. Part of this effort included the construction of a uranium refining mill at Grand Junction, Colorado, and the reopening of the mill at Monticello, Utah, in 1948 (Mehls and Mehls 1986:167).

The stage was set for the crazy scene of the uranium rush in the 1950s by a few events in the late 1940s. In 1948 the AEC established an ore-buying schedule and began to purchase uranium-vanadium ore at the government-owned mill in Monticello (Utah Geological and Mineralogical Society 1954:8). The discoveries of large and lucrative quantities of uranium ore by individual prospectors in the late 1940s attracted people hoping to strike it rich to the Colorado Plateau. Pratt Seegmiller, a retailer and part-time prospector, located the famous Marysvale, Utah, deposits in 1947. Other individual prospectors found large deposits in the Colorado Plateau area. As these strikes captured the public's imagination, people flocked to the area. The number of claims began to grow. San Juan County, through the end of 1947, had only 94 uranium ore claims filed in it. In 1948 prospectors filed 292 claims (Mehls and Mehls 1986:168). Uranium fever was spreading. Between 1941 and 1952, the government raised uranium prices as much as 300 percent and offered a major bonus for initial production. Of the first five mines to receive a special bonus for ore production in 1951, three were located in the immediate Moab area (Tanner 1976:219). As the AEC continued to increase the price it offered for uranium ore and to implement larger bonuses for ore discovery in 1950 and 1951, only one more event was needed to excite the uranium frenzy. Charles Steen became the catalyst for the chain reaction of events that would transform Moab from a sleepy agricultural community to the quintessential boomtown. In a now famous story, Charlie Steen, a prospector down to his last pair of worn-out field boots, discovered a deposit of rich uranium ore in July of 1952. Within a year, Steen had removed over $1.3 million dollars in uranium ore (Newell 1976:16).

Steen's meteoric rise to riches attracted thousands to the Moab area. Charlie Steen was Everyman. If he could become a millionaire, then anyone willing to stake a claim could as well. San Juan County recorded about 2,900 uranium claims in 1952. After Steen's discovery, that number catapulted to almost 98,000 within two years (Weber 1979:176). Some of these claims were located in what would become the Island-in-the-Sky District.

A number of the rock formations identified as favorable for uranium deposits crop out in the Island area. The oldest formation is the Permian Cutler. The Cutler Formation includes a number of members, the Cedar Mesa sandstone, Organ Rock shale, and White Rim sandstone, that are exposed in the Island area. The Cutler Formation contains many small uranium-copper deposits. A favorable location for uranium within the Cutler occurs as the Cutler grades from the white aeolian sandstone of the Cedar Mesa member to predominantly fluvial arkosic red beds (Johnson and Thordarson 1966:H39).

The Chinle Formation of the Triassic period also contains concentrations of uranium ores. The Chinle and the underlying Moenkopi Formation compose the talus slopes below the cliff-forming Wingate and Kayenta formations below the Island mesa. The Moss Back Member of the Chinle serves as the basal unit of the formation resting unconformably on the Moenkopi Formation. Uranium ore in the Moss Back is associated with channel scars carved in the Moenkopi. In the Island area the Moss Back Member was the most important ore producer in the 1950s.

The most famous mine in the Island area was the "C" group. The "C"group actually included 27 individual and overlapping claims. The claims were made in 1951 and were leased to Paradox Mining Company in 1952 (deVergie and Carlson 1953:6). The claims lay at the base of Howard Lathrop's sheep trail that led from Gray's Pasture on the Island top to the White Rim. Miners excavated adits into the Moss Back Member of the Chinle Formation. As part of a historic resources study of Canyonlands and Arches national parks and Natural Bridges National Monument, Carol Mehls and Steven Mehls (1986) compiled a List of

Classified Structures (LCS) with survey forms for these areas.

The uranium boom spurred much of the road development in the Island area. In March of 1953 when deVergie and Carlson reported on the "C"group claims, a road that would continue southward from the base of the Shafer Trail was under construction. This road would become the White Rim Trail. Before the construction of the White Rim Trail, mules hauled the ore from the"C"group mines up the Lathrop Trail to stockpiles at the end of the nearest access road (deVergie and Carlson 1953:6). Obviously, the difficulties of transporting the ore limited the development of uranium claims on the White Rim in the early 1950s.

The Shafer Trail was the first route in the Island area to be improved because of the uranium boom. The Shafer Trail existed as a stock trail from the mesa top to the White Rim. John L. Shafer (in Tanner 1976:298) recalled that the trail that his father John H. Shafer and his uncle Frank Shafer had built and used for their stock in the 1910s was first improved by Moab residents Nate Knight, Jr., Nick Murphy, and young Felix Murphy with a tractor and four-wheel-drive truck in 1953. A few years later the AEC surveyed the road and contracted for a good road to be built. This road continues to serve as the access to the east side of the White Rim from the Island mesa. The White Rim Trail was another road constructed with the encouragement of the AEC. The roads constructed during the uranium boom opened up the canyonlands area to people other than the stockmen for the first time.

With the improvement of Shafer Trail and the construction of the White Rim trail, mining companies soon contracted for other roads to be built to individual claims. The seemingly random pattern of abandoned road scars that can be seen today on the White Rim resulted from the feverish activity of the 1950s. Many of these roads led to the same area, because bulldozer operators were paid by the amount of dirt moved to create new roads. An operator would not be paid for using an already existing road (Pierson 1985:18). At White Crack, road builders blasted through a gap in the White Rim sandstone that had been used by ranchers and graded a rough route down to a bench on the Cedar Mesa sandstone. Following this bench on its meanderings as canyons from the Green River cut back into it, the road continued its sinuous path to the south for a few miles. At this point the road diverged into a number of branches on a broad bench above the Colorado River near its confluence with the Green. The remains of cabins have also been identified along the course of this road, as has a dirt airstrip (National Park Service n.d.). The author has hiked this road along much of its course and observed historic trash consistent with a 1950s period of construction and use.

A map of uranium mines and prospects located in the Island area through 1955 (Johnson 1959:Plate 6) identified a number of mines within the present Island-in-the-Sky District. All of these prospects were on the White Rim. Besides the "C" group found at the base of Lathrop Trail that was discussed above, other prospects in the area included an unidentified prospect also on the White Rim near the "C" group, the George No. 3 prospect down Lathrop Canyon below the White Rim, the Sailor and Rainy Day groups on the White Rim around Buck Canyon, the Hot Rim and Soda Roll prospect and the Rainbow group on the west side of the White Rim near Murphy Hogback, and several prospects in Taylor Canyon and its side canyons. All of these prospects examined the strata in the Cutler Formation, except the George No. 3 prospect located in the Cutler Formation below the White Rim sandstone. All of these prospects produced less than 100 tons of ore, with the exception of the "C" group, whose several claims produced between 1000 and 10,000 tons through 1955. The prospects of those who constructed the road from White Crack through the White Rim sandstone and to the south were not recorded on this map.

A map illustrating the uranium prospects and production totals to January 1959 (Williams 1964) documented the "C" group prospects and George No. 3 in Lathrop Canyon, as well as other prospects just south of the "C" group near Washer Woman Arch, a few prospects on the White Rim in the Moss Back Member near Buck Canyon, prospects around Monument Basin in the Moss Back Member and in the Cutler Formation, prospects on the White Rim near Murphy Hogback, and prospects in Taylor Canyon. All of these prospects produced less than ten tons of uranium ore. In addition, this map located uranium prospects whose concentration of uranium was too low to ever have had ore removed.

The Cutler Formation functioned as a favorable trap for uranium deposits in the zone where the aeolian Cedar Mesa sandstone changes to predominantly fluvial arkosic red beds. The interfingering of

these two facies represented the transition from subaerial basins to the quiet waters of slowly sinking continental margins (Johnson and Thordarson 1966:H39). This particular zone occurred approximately two miles south of White Crack (Williams 1964), where the jeep road branched into a number of segments. Perhaps the drillhole at White Crack furnished cores in which the prospectors recognized the arkosic beds. Knowing that to the south of White Crack they would find outcrops of the interfingering of the aeolian sandstone and red beds, the prospectors constructed the jeep road below White Crack. The George No. 3 prospect in Lathrop Canyon was located in similar deposits of the interfingering of two facies. Those industrious individuals who blasted and graded the road from White Crack through the White Rim sandstone for miles to the south never located a rich enough prospect to have had its name or location preserved. As a result no record remains of those hopeful miners but the trace of a now closed road.

The uranium boom ended almost as quickly as it began. Soon after its start, the character of the boom changed. The costs of extracting the uranium ore increased by 50 percent between 1951 and 1955. Lone prospectors could not afford to extract the ore they located. Claims became consolidated. In San Juan County in 1956, 12 companies supplied 78 percent of the uranium. By 1958, only eight companies supplied nearly all of the local output. Phillips Petroleum, National Lead and Zinc, Humble, Cities Service, and Anaconda Copper Company became only a few of the multinational corporations who entered the local uranium industry. The uranium extracted was sold only to the federal government. By 1958 the AEC had stockpiled more than enough uranium for defense and peacetime purposes. The AEC, consequently, announced the end of discovery and development bonuses and instituted restricted purchasing policies. Only large corporations with well-developed mines could continue production under these revised rules. Local uranium production began to decline in 1959. The existing contracts continued until 1962. The mining corporations pushed production under these existing contracts. Each year until 1961 showed an increase in production. After the expiration of the contracts, uranium production declined until a slight resurgence appeared from 1968 through 1979, when peacetime uses for atomic energy increased the demand. The accident at Three Mile Island and the increased use of foreign uranium slowed production once again (Weber 1979:176). With the closing of the Atlas uranium mill in Moab in 1984 (The Times-Independent 1987) uranium production in the Moab area essentially ceased.

Prospectors staked a number of uranium claims within what is now the Island-in-the-Sky District. Small amounts of ore were removed from several of the claims on the White Rim in the early years of the boom. As production costs increased, the Island-in-the-Sky area saw fewer of its claims mined. The area did not contain any uranium deposits large enough to justify the capital investment needed to develop them. By the mid-1950s, exploration on the White Rim had slowed considerably. Most of the claims were probably abandoned by the late 1950s. Even though the uranium boom did not result in the development of large mining complexes in the Island and White Rim areas, the frenzy of those first years of exploration opened the area for the first time to people other than cowboys or sheepherders. The Shafer Trail was improved from a stock trail to a jeep road and the White Rim Road was constructed. Numerous other roads to mining claims were also graded on the White Rim and below. The scars of many of these now closed roads can still be seen. Besides the construction of roads, the uranium boom also encouraged the systematic mapping of the entire area. Accurate topographic maps of the many regions were produced for the first time.

Public Law 88-590 of September 12, 1964, created Canyonlands National Park. Public Law 92-154 of November 12, 1971, expanded the park to its present size of 336,680 acres. All lands within the park boundaries were withdrawn from mining claim activity upon the date of these public laws. Any claims made before these lands became part of Canyonlands National Park remained valid. Over 20,000 unpatented claims have been catalogued within the park's boundaries. Over 4,000 of these have been officially relinquished or invalidated. The Island-in-the-Sky District contains no outstanding mineral leases (National Park Service 1977:7).

The Island-in-the-Sky area had been known to cattlemen since the early decades of this century. Cowboys and sheepherders passed through the area as they used the mesa top and the White Rim for grazing of their livestock. Early miners may have explored in the area, but never improved upon what claims they may have made. The first true development of the area came with the advent of the uranium boom in the early 1950s. Road building opened up the mesa top and the White

Rim to jeeps. The improvement of the Shafer Trail and the Mineral Bottom Road allowed people to travel from the mesa top to the White Rim and back. When Marguerite and Howard Lathrop returned in 1954 to the land where they had run sheep, they saw jeep roads in all directions, with pickets marking claims. Howard Lathrop remarked:

> I predicted lots of people would come to the canyon, didn't I? No prophet can see the future as bad as it really is. I prefer mules to jeeps; they don't tear up the country. Now that sheepmen can go down in their pick ups, every sheepherder might be using a jeep. But I thought it would be scenery that would bring people. How could anyone dream that the blue clay I used to seal my reservoirs contained stuff more precious than gold (Lathrop 1972:339).

Although the drilling and exploration in the area never proved productive, the frenzy of activity of that time forever changed the Island. Not long after the uranium rush halted, the Island-in-the-Sky became part of Canyonlands National Park.

ARCHEOLOGICAL RESEARCH PROGRAM

INTRODUCTION

Archeological investigations for the Island-in-the-Sky project were guided by both cultural resource management concerns and a set of general research questions. The methods used for pedestrian survey, surface artifact mapping, subsurface testing, and data collection were based on federal guidelines, standardized archeological techniques, and contemporary, innovative approaches to fieldwork. The general directions for archeological investigations were formulated in a general research program written by Osborn and Hartley (1984). This problem statement was originally developed as a framework for archeological work within the region's national parks.

This research program identified four general problem areas concerning prehistoric human adaptations in southeastern Utah and the Greater Southwest in general. These problem areas included: 1) land use strategies; 2) food storage; 3) diet, nutrition, and health; and, 4) rock art. These four problem areas were selected on the basis of their broad applicability to Southwest archeology, the specific characteristics of southeast Utah prehistory, and their theoretical implications for anthropology. Each problem area is sufficiently complex to allow archeologists to formulate project-specific questions and to utilize a range of diverse data sources to test conceptual models about past human lifeways. The initial formulation of this research program was meant to serve the following purposes: (1) to define research problems that would involve foraging, collecting, and cultivating as components of past human adaptations in this portion of the Colorado Plateau; (2) to operationalize archeological research that is relevant to contemporary archeology and anthropology; (3) to elucidate archeological questions that are specific to areas of the Colorado Plateau circumscribed by the region's national parks; and (4) to provide information that will facilitate cultural resource management, i.e., inventory, assessment, preservation, interpretation, and mitigation within national park lands.

Components of the original research program served as a general framework for additional archeological studies in southern Utah. These additional archeological investigations were conducted in Lavender Canyon (Osborn et al. 1986) and at the White Crack site (42SA17596) in Canyonlands National Park and the Halls Crossing site (42SA14829) in Glen Canyon National Recreation Area (Osborn et al. 1993), at the North District Campground site (42WN1651) in Capitol Reef National Park (Osborn, Vetter, and Hartley 1987; Osborn, Vetter, Hartley, Walsh, and Brown 1987), in the Spendlove Knoll—Cave Valley area of Zion National Park (Burgett 1990a), at Natural Bridges National Monument (Kramer et al. 1991), and at Arches National Park (Kramer 1991). Our initial concern with artifact and rock art variability and diversity measures was developed and elaborated in master's degree theses by Baumann (1989) and Kramer (1990) and in a doctoral dissertation by Hartley (1989). In addition, human osteological collections were examined that were recovered from the Polley Secrest site in Moab, Utah, and the immediate area. Sacral pathologies related to spina bifida occulta and zinc deficiency were analyzed by Wolley (1988) for her master's thesis.

For the Island-in-the-Sky project in Canyonlands National Park, our problem emphasis shifted more toward aboriginal land use and food storage strategies. The general land use model focused on collapsed winter home ranges in the higher elevations and expanded summer home ranges in the lower, more arid areas. This expanded component of the original research program is presented later as a separate chapter. Special attention was given to translating the land use models into a set of archeological correlates. Artifact scatters located during the Island-in-the-Sky project were examined in the contextual framework of distributional archeology. Considerable effort was devoted to the development of appropriate measures of artifact assemblage variability and pattern diversity. This component of our research was developed in order to monitor variable or redundant use of specific locations on the Island-in-the-Sky. This research demonstrates that surface artifact scatters provide significant insights into the nature of prehistoric mobility, resource procurement, and life maintenance activities in this region.

DEVELOPMENT OF AN ARCHEOLOGICAL RESEARCH PROGRAM

Scientific research is frequently portrayed as an exploration of the unknown or an investigation designed to discover new phenomena. Yet, novel insights may be gained simply from looking at familiar subjects in a new way. Novel insights may also be achieved through a more effective integration of seemingly disparate bodies of knowledge. A scientific approach to archeology provides a means for systemically linking together innumerable observations about the prehistoric Southwest, in order to form a comprehensive picture of aboriginal lifeways. Such a picture consists not only of a summary of all that archeologists have observed, it also offers new facts and insights into prehistoric life. This interpretative picture of the structure and dynamics of prehistoric life in the American Southwest ultimately will be provided through theory construction. Theory is essential for gaining an understanding of the empirical world. Harvey (1969:158) states, "The main aim of theory construction is to expose the 'order in seeming chaos' and consequently to allow information derived from certain individual cases to be brought to bear on other individual cases."

We can expect to find that such theoretical frameworks continually change in order to accommodate reality, to predict "new facts," and to direct further research programs. Scientific archeology is not, then, an obsessive search for a final interpretation of the past. Cohen (1970:33) states, "As science develops, there is a constant tendency for more elaborate and refined theoretical development, as well as more carefully controlled and theory-directed observation."The tremendous utility and power of science derives from its "openness and changeability"(Cohen 1970:31). The initial version of the research program for southeastern Utah was meant to be an "open and changeable" approach to archeological problems throughout this region.

Several explanatory models will be examined in the following study. These archeological and ecological models are expressions of the causal interrelationships between select variables. Models "may be regarded as a simplified structural representation of the theory"(Harvey 1969:148). Harvey (1969:146) also points out that, "An important function of the model ... is to provide an interpretation of the theory ...." The models presented herein will enable us to separate aspects of the empirical realm that we understand from the anomalies and deviations that we do not understand. Moore (1981b:197) envisions a model as"an ideal construct, a research instrument against which the complexity of the world is gauged." In many instances, Moore (1981b:197) states:

> The patterning of deviations from the model becomes the focus of the research; hypothesis testing is no longer the major concern of this approach to research. Variability not explained by the model is analyzed to locate the existence of factors which identify how the specific case at hand differs from what are thought to be the general features of the problem.

One might add here that empirical cases that fail to conform to our expectations may provide direction(s) for developing new or related models to direct future research. The following study of the archeological record in Canyonlands National Park in Utah is concerned with extant theory and related models. Empirical observations are utilized to evaluate current ideas regarding past human adaptations to environmental constraints in southeastern Utah and the Greater Southwest in general. Positive, as well as negative, feedback loops link theory formation and evaluation operations. Research questions were modified throughout the course of this project in order to conform to pragmatic concerns regarding the nature of the archeological record, and to the changing course of archeological method and theory. Initial ideas, preliminary models, and hypotheses were evaluated on the basis of field observations, the nature of the archeological record, and developments in archeology, anthropology, and ecology.

ARCHEOLOGICAL RESEARCH PROGRAM: AN INITIAL FORMULATION

The original research problems and their operationalization are illustrated in Figure 4. As mentioned, the changes and elaboration of this original problem orientation are represented in Figure 5. In order to develop a series of appropriate problems for this research program, we called upon contemporary studies in anthropology, archeology, and ecology to isolate significant issues and questions. For example,

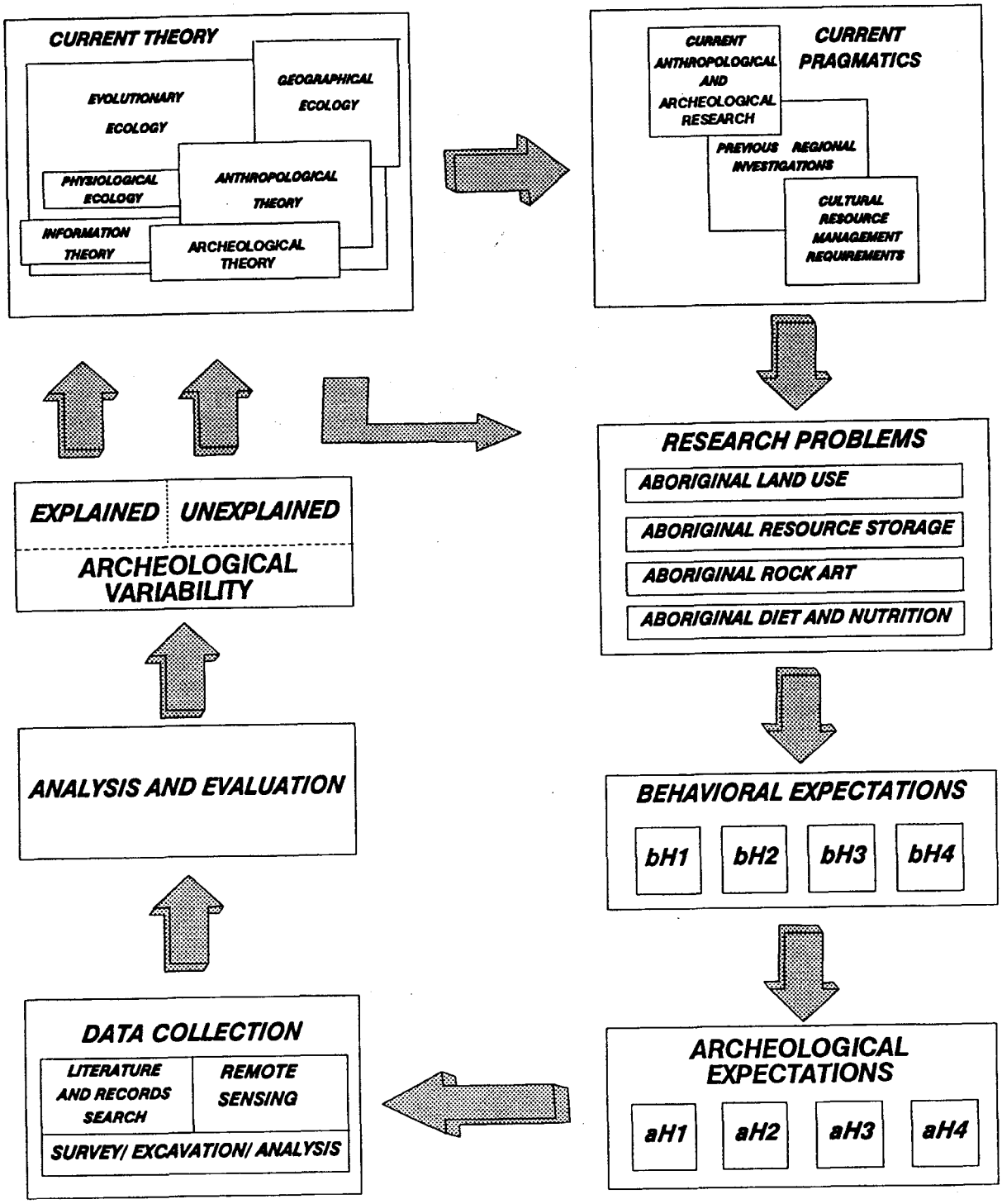


Figure 4. Schematic representation of original research program.

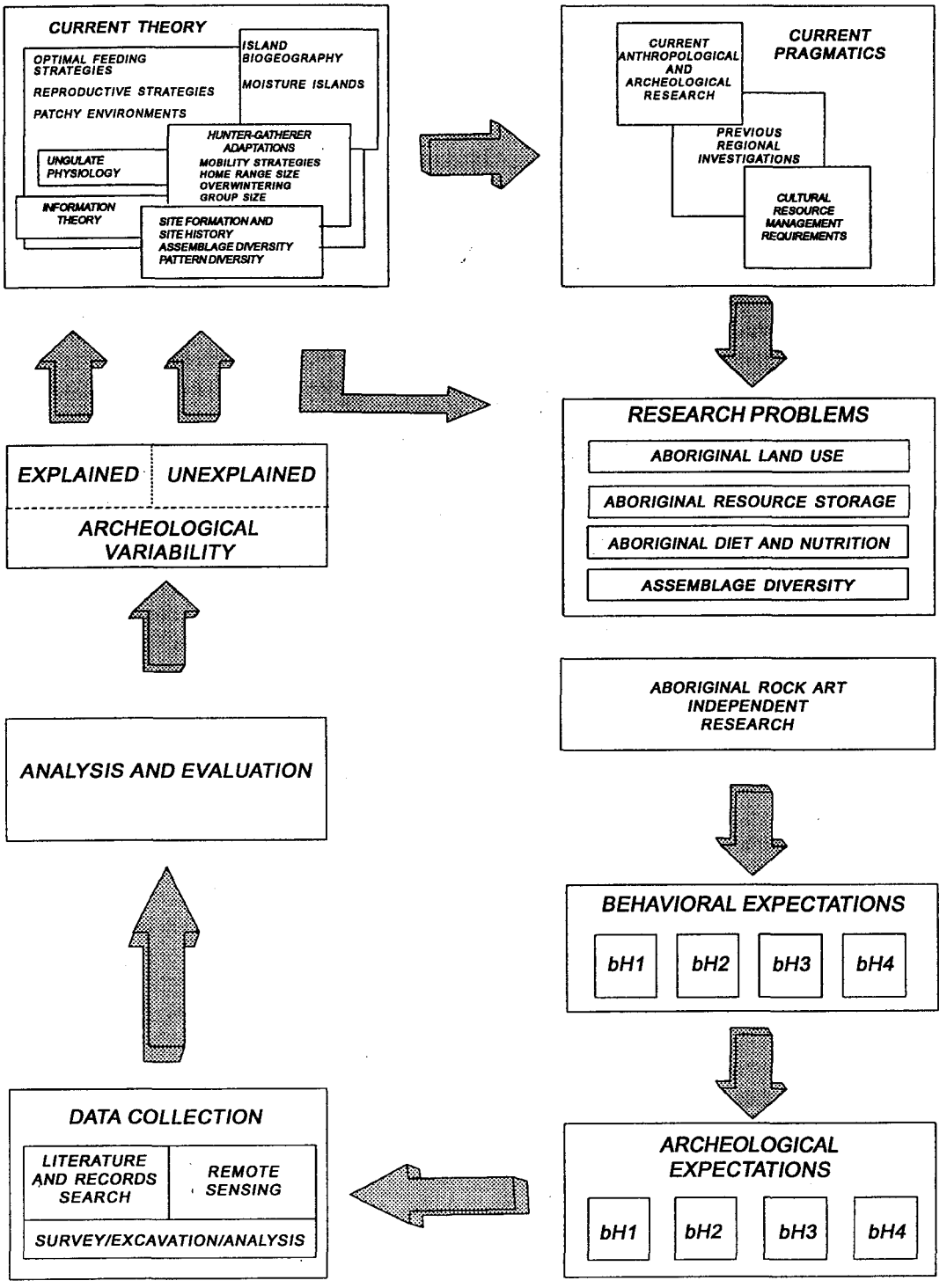


Figure 5. Schematic representation of the modified research program.

considerable attention has been given recently to optimal foraging theory in evolutionary ecology (e.g., Charnov 1973, 1976; Pianka 1983; Pulliam 1974; Pyke 1984; Pyke, Pulliam, and Charnov 1977; Schoener 1971; Stephens and Krebs 1986) and anthropology (e.g., Belovsky 1988; Bettinger 1991; Hames and Vickers 1982; Hawkes and O'Connell 1981; Simms 1984a, 1987; Smith 1983, 1991; Winterhalder and Smith 1981).

In addition, Binford (1980) has presented a global model which may be used to account for variability of hunter-gatherer societies, particularly with respect to subsistence activities and mobility patterns (Kelly 1980, 1983b). We suggest here that Binford's (1980) global hunter-gatherer model is based in part on geographical ecology and may serve to develop appropriate currencies and conditions for optimal foraging models. As one will see, we have relied heavily on Binford's (1980, 1982, 1983) models for hunter-gatherer adaptations. We have tried to extend this discussion to include horticultural systems.

Furthermore, our interest in aboriginal food storage strategies was derived from contemporary research in anthropological archeology and evolutionary ecology (e.g., Binford 1978b, 1980; Glassow 1972a, 1972b; Hunter-Anderson 1977; Schalk 1977, 1978, 1981; Testart 1982; D.H. Thomas 1981, 1983a; Vander Wall 1990). Implementation of a food storage strategy has a number of implications for the organization and character of aboriginal societies. Food storage is systemically linked to land use patterns, degree of mobility (residential versus logistical), diet, health, and demography. These interrelationships will be discussed in the following sections.

Our concerns with paleonutrition, paleopathology, and paleodemography stemmed from recent archeological research that focuses on the shift toward horticulture and its associated stresses on human populations. Many of these studies have been conducted in North America, and they have dealt specifically with the adoption of maize horticulture. Anthropologists have been re-evaluating the nature of agriculture, and these archeological studies have served to point out yet another set of detrimental impacts. The recent development of trace element and carbon isotope analyses, which reveal reliable information about prehistoric diet, has provided archeologists with a powerful tool for investigating past lifeways.

Finally, we suggest that recent concern with information acquisition, storage, and transmission in both anthropology and archeology has enabled archeologists to examine aboriginal rock art from a new perspective in this region. Many current studies have used information theory to develop scales of sociocultural complexity and to monitor evolutionary change in both the present and the past. Information has also been only recently mentioned with respect to risk minimization in optimal foraging strategies. Such developments in evolutionary ecology may provide valuable insights into how rock art may have functioned throughout the region to moderate information flow among foragers, collectors, and horticulturalists.

Aboriginal Land Use

Anthropological archeologists are concerned with the variable nature of past human land use throughout space and time as it is reflected by the distribution of material remains. Explanations of variation in past human behavior in relation to the natural and social environment constitute the broad, yet recurring, challenge to anthropological archeology. Prehistoric land use thus constitutes one primary theme in the proposed research of the study area.

Prehistoric man-land relationships can be examined in terms of the subsistence practices employed and the settlement and mobility strategies resulting from these practices. Perhaps the most productive manner in which to view the way that hunter-gatherers organize themselves across the landscape is by recognizing the variables that account for the mobility strategies they employ (Binford 1980; Kelly 1980, 1983). D.H. Thomas (1981, 1983a) has recently adopted this suggestion to help explain the variability in the subsistence-settlement patterns observed in the Great Basin.

Archeological investigations of "sedentary" Anasazi populations reveal that although horticulture played a role in the subsistence base, the collection of wild plants and the hunting of small game played an equal, if not more important, role in food procurement (e.g., Cordell and Plog 1979; Efland et al. 1981; Hill 1970; Longacre 1970; Powell 1983; Sullivan 1987). Evidence of settlement among populations that employed horticulture in the vicinity of the study area also suggests that these groups did not reside in one place throughout the year (e.g., Powell 1983, 1988). An

understanding of the role that mobility played in the subsistence-settlement strategies of human populations in the study area is then deemed a necessary component of research aimed at explaining the variability in prehistoric spatial organization and land use through time.

> Prehistoric man operated over a landscape, and his survival depended on his ability to organize his activities over this landscape. His immediate dimension is also the one on which we should map our understanding of his behaviour (Foley 1981b:180).

Foley (1981a:2) has recently put forward the proposition that "the archeological record is spatially continuous, and that its structure may be described in terms of variable artifact density across a landscape." He (1981a:2) states:

> The energy necessary for survival is distributed widely and continuously across the landscape, and to gather this energy man will use large areas of the landscape, and only secondarily transport the resources to focal points, i.e., settlements, processing camps, etc. The archaeological inference to be drawn is that human activities are not centered solely on settlements or home bases, that may ultimately be preserved as archaeological sites, but are distributed fully across the landscape. In this perspective settlements become points on the landscape where a high frequency of activity occurs, and the difference between various parts of the landscape become one of degree and not kind (Foley 1981a:2).

Economics of the Forager-Collector Continuum. Ethnographic descriptions of subsistence practices among populations throughout the world have often been assessed in "typological" terms and have tended to obscure the character of actual ecological adaptation. Cordell and Plog (1979) have recently pointed out that attempts to generalize about "cultural" patterns in Puebloan prehistory have masked "regional and local diversity" and, hence, variability in subsistence practices. In an attempt to structure the subsistence and settlement practices of ethnographically observed mobile "hunter-gatherers," Binford (1980) has utilized economically oriented terms to categorize the extremes in strategic systems of aboriginal subsistence practices. Binford (1980) uses the term "forager" to describe one end of the continuum where consumers are moved to goods with frequent residential moves. At the other end of the continuum the term "collectors" is used to describe circumstances where goods are moved to consumers with far fewer residential moves. These terms are more sensitive for analyzing the variable subsistence of the study area.

Aboriginal Home Range and Mobility Patterns. The spatial variation in rainfall, run-off distribution, and edaphic diversity has been attributed to the observed resource patchiness in arid environments. This resource structure affects both species diversity and the adaptive behavior of organisms in the environment. This adaptation is observed in highly mobile organisms compensating for temporal variability and low spatial correlations in precipitation. "Opportunistic migration" is well known for some birds and large mammals in arid zones and is likely necessary for the survival of the organism. Noy-Meir (1973:33) concludes that the "inclusion of such nomadic populations in ecosystem models requires modeling at a regional rather than a local scale."

Human groups can be extremely mobile, and they can monitor resource conditions over a vast area. Critical knowledge of the resource structure is often crucial to survival, and it is generally expected that there will be greater need to monitor resources as seasonality increases (see Kelly 1980:22-23). Furthermore, the location of water, its transport and storage, and minimization of its loss constitute the central problem of human adaptation to conditions in arid environments. Behavioral responses to unpredictable arid lands, therefore, constitute an important topic for research in this region of southeastern Utah.

The concept of range as a unit of analysis in the investigation of spatial behavior is well developed in the biological and ecological sciences. Use of this concept in anthropology is somewhat more limited (see Foley 1977; Hill 1969). Southwood (1977:343) has suggested that most organisms operate spatially on two scales, foraging range and migratory range. It might be added that humans behave in a manner which potentially adds

a third scale determined by the interactions of exchange (see Wobst 1978).

The concept of "home range," taken from animal ecology (see Pianka 1978:146), is useful in organizing the relationship between human populations and resources. Home range refers to the area habitually exploited by an individual, or in this case, by a small population. Home range is differentiated from an organism's "territory" in that the home range is not defended and not used exclusively by an individual or small group (Dyson-Hudson and Smith 1978). The concept of home range enables us to model human settlement-subsistence systems in spatial terms (Binford 1982:6-8; Foley 1981a:2-8). Binford (1982:6) points out that "One of the more distinctive features of human systems is their spatial focus on a 'home base' or a residential camp. At any one time the way in which a group uses its habitat is directly conditioned by the pattern of moving out and then returning to a residential camp." Analysis of the adaptive strategy employed by aboriginal groups will depend on the way in which the internal structure of the home range varies (Foley 1981a:4).

Kelly (1980:17-24; 1983:283-287) has identified two key characteristics, determined by environmental differences, that can be attributed to the variability in the mobility structure of hunter-gatherers: (1) resource accessibility—"the amount of time and effort required to extract fauna and plant resources from an environment"; and (2) resource monitoring—"the degree to which the locus of a resource's exploitation must be monitored by hunter-gatherers in order to insure the successful exploitation of that resource."

Home range size tends to vary inversely with density of food resources. In arid environments, where resource density is regulated by precipitation, home range size has been shown to have an inverse relationship with precipitation (see Schalk 1981). Home range size is also considered to be determined by the degree of resource clumping. As Wiens (1976:97) states "as the spatial or temporal clumping of resources ... increases, an increasingly larger area is required to ensure an adequate supply..." In environments such as southeastern Utah where precipitation is low and resources are highly clumped, we would expect extensive home ranges and greater mobility among aboriginal populations practicing little or no horticulture (e.g., Kelly 1934; 1964). Based on data collected by Steward (1938), the average home range used by Great Basin hunter-gatherers equaled approximately 10,000 km^2.

Two dimensions of patterned movement have been suggested by Binford (1980) to exemplify the economies of the forager-collector continuum. These dimensions of mobility are defined simply as: (1) residential mobility, the movement all members of a camp unit from one place to another; and (2) logistical mobility, the movement of individuals or small groups from a residential location for the purposes of resource acquisition, exchange, etc. Variability in a group's mobility strategy will reflect responses to seasonal and longer range fluctuations in the environment and the need to monitor resources (Kelly 1980:36-37; 1983:277-279). Therefore, aboriginal groups can be expected to invest energy in both residential and logistical mobility when dictated by the spatial and temporal structure of resources.

Kelly (1980,1983) has focused on the mobility strategies of ethnographically described hunter-gatherers and demonstrated that generally groups living in high primary biomass environments move their residences quite frequently between centers of foraging areas. The frequency of residential moves is reduced when a storable resource is present in the environment, usually a strategy which enables survival during the winter season (Binford 1978b, 1980).

The mobility of groups occupying low biomass areas such as arid environments is dictated by the nature and distribution of water sources. Where access to water is limited and exploitable in discrete places we would expect, as Binford (1980:7) suggests, "tethered nomadism" or the reoccupation of particular places to be the rule. Taylor (1964:199) suggests that an explanation for the occurrence of residential sites close to the mouths of canyons and in canyon cliffs in northern Mexico was a result of proximity to two resources necessary for survival, food and water. Adequate food resources existed only in the "monte," and dependable water existed only in the watered mountains. The actual pattern of land use might represent what would appear to be loops that range out from a residential camp and return. That is, the range of activities of these groups would be conditioned by their efficiency in logistical mobility and their maintenance of information about critical resources.

The spatio-temporal structure of resources in an environment is also believed to play a determining role in the distance between residential sites, as well as the number of residential moves made by an aboriginal group. As biomass increases, plants expand into more niches, contributing to the overall homogeneity of the environment, and the distance between resource patches decreases. As a result we expect decreased average distance per residential move for hunter-gatherers. As food resources become more dispersed, however, we would expect an increase in residential mobility (Kelly 1980:68).

Binford (1982:9-10) recognizes three basic residential mobility patterns: (1) the classic foraging pattern where residential mobility is high, exploitation of foraging radius is incomplete, and a logistical zone is non-existent (in this case, occupation of a site is very brief, possibly just overnight); (2) a similar foraging pattern in high-biomass settings, where the population is highly mobile and the logistical radius of each residential camp overlaps to include a previous residential camp, as well as portions of the former foraging zone; and, (3) "point-to-point" residential mobility, which is more common in low-biomass environments where a group moves from one optimal location to another. For example, Binford (1982:9-10) cites hunter-gatherers in Australia and the Kalahari as indicative of residential movement from one point source of water to another.

These generalized patterns of residential mobility cannot be, in most cases, viewed as exclusive to either foragers or logistically organized collectors. Binford (1982:11) points out that the pattern of highly mobile groups in the first settlement pattern described is exclusively characteristic of foragers, while the second pattern and point-to-point patterns are found both among foragers and logistically organized groups.

An aboriginal group utilizing organized task groups to procure and transport food resources back to the residential site must rely on extensive logistical mobility. Within the framework of Binford's (1980) forager-collector continuum model, collectors are characterized by (1) food storage for a portion of the year and (2) logistically organized parties to procure food, nonfood resources, and information about those resources and competition for those resources.

Cultivators and Land Use. In this study, we will extend the "forager-collector continuum" proposed by Binford (1980) to include horticultural strategies (Table 1). There are several reasons for the extension of the forager-collector continuum. First, horticultural groups must develop logistical organization in order to obtain essential resources other than the staple crop(s). The cultivation and storage of specialized plant foods can be energetically and nutritionally expensive, but these liabilities are, at times, outweighed by the reduction of the risk inherent in mapping onto a fluctuating resource structure. Archeological investigations have for years revealed the employment of horticulture in the study area; however, there is much evidence to suggest that prehistoric diets were more diverse than traditionally assumed (e.g., Powell 1983, 1988). Crop production was probably highly variable through time and space and was possibly a component in the exchange of food (see Lightfoot 1979). We have viewed the cultivation and storage of crops in the study area as one option available to logistically organized groups. Binford (1980:18) has suggested that conditions (e.g., resource incongruity) that restrict high residential mobility among foraging populations favor logistically organized procurement strategies and "tend to expect some increase associated with shifts toward agricultural production."

Second, the relative dependence on maize and other domesticated food resources in this region in general has not been assessed until very recently (Matson and Chisholm 1991). Considerable discussion has been devoted to the so-called "Fremont-Anasazi" question in Utah (e.g., Aikens 1966a, 1966b, 1979; Ambler 1969, 1970, 1980; Anderson 1983; Berry 1980; Gunnerson 1957, 1969; Jennings 1978; Madsen 1979, 1980; Marwitt 1970, 1979, 1980; Morss 1931; Sharrock and Marwitt 1967; Taylor 1954; Wormington 1955). Even though most investigators have entertained the notion that Fremont peoples continued to hunt and gather wild resources (e.g., Morss 1931:76-77), an overriding emphasis has been placed on maize horticulture. Anderson (1983) summarizes many of the discussions of the "Fremont culture" and posits six "models" for its development (the Diffusion, Athapascan, In Situ Development, Virgin-Shoshonean, Shoshone Expansion, and Subsistence models). Anderson (1983) resolves (or perhaps compounds) this cultural historical confusion by presenting a "Composite" model. Whatever position one chooses to follow, we do recognize that the subsistence

activities of aboriginal peoples assigned to the "Fremont culture" are variable, ranging from aquatic resource use in the Sevier-Fremont to some degree of horticultural dependence in the Colorado Plateau (e.g., Aikens 1979; Madsen 1979; Marwitt 1979). Since our initial formulation of the research program for southeastern Utah (Osborn and Hartley 1984), a number of papers have re-evaluated previous characterizations of the Fremont culture (Lindsay 1986; Madsen 1989; O'Connell et al. 1982; Sharp 1989, 1990; Simms 1984, 1986, 1990).

Simms (1986) discusses several adaptive strategies that may have been utilized by a number of prehistoric groups classified within the Fremont culture, including the Uinta, San Rafael, Great Salt Lake, Sevier, and Parowan sub-areas. The observed archeological variation might also be re-examined with respect to the variable cost-benefit ratios of wild plants, game animals, and domesticated plants (Simms 1984a, 1986). Prehistoric dependence on maize in Utah might also be viewed as a function of Bailey's (1981) aridity index or the coefficient of variation in the mean length of the growing season. Much of the confusion regarding "Fremont culture" could then be conceptualized in terms of environmental and demographic variability through space and time. Subsistence activities in this region could then be viewed as adaptive responses to basic environmental differences between the lacustrine and riverine areas adjacent to the Great Salt Lake, the short grass plains of northeastern Utah, and the marked topographic and ecological variation of the Colorado Plateau.

Recent archeological work throughout the American Southwest has produced a picture of adaptive diversity, particularly with respect to diet. Discussions of prehistoric dietary variation, including wild plants, game animals, domesticated plants, domesticated animals (e.g., turkeys), and food redistribution and trade, are provided for the Hohokam (Fish 1989), Grand Canyon Anasazi (Efland et al. 1981; Sullivan 1987); Black Mesa Anasazi (Powell 1983, 1988), San Juan Basin Anasazi (Judge 1989; Minnis 1989; Toll 1983), and the northern and central Rio Grande Anasazi (Cordell 1989).

Archeological Correlates of Land Use. The spatial organization of a group's activities can be conceptualized from the vantage point of a residential site on the landscape. Binford (1982) has suggested that logistically-organized economic systems can be examined with respect to zones that extend beyond the residential site. He delineates the logistics of activities within the home range, including the foraging radius (utilized by groups and individuals for the procurement of resources during a single day); the logistical radius (where specialized task groups operate throughout the area for weeks at a time in search of resources); the extended range (individuals attempt to keep informed about the changes in resource distribution); and a visiting zone (within which the camps and activities of other groups are known). Knowledge of those areas beyond the logistical range are necessary for making decisions about future residential moves.

Foley (1981a:3) demonstrates that archeological correlates of this kind of behavioral system as revealed through "the processes by which material items relating to human behaviour are disposed of subsequent to or during use, such that they come to rest on or in a landscape." Foley (1981a:3) states:

> If activity is spatially continuous and home range-specific then through the process of discard the material manifestation of that activity should also be continuously distributed. Ultimately there should be a patterned residue of material remains that in some way, although not necessarily directly, reflects the behaviour of the population. The result is an archaeological pattern of variable artifact density and distribution that conforms to the subsistence strategy and home range.

Binford's (1980) functional terminology has enabled archeologists to understand better the potential range of activities of hunter-gatherers reflected in the archeological record. Behavioral and archeological expectations are summarized in Table 1.

Those groups employing a foraging strategy will often exhibit a high number of residential camps and a high number of resource procurement locations during their annual cycle. On the other hand, the activities of logistically-organized groups will, in addition to residential camps and resource procurement

Table 1. Behavioral and archeological characteristics of foragers, collectors, and cultivators.

	Adaptive System		
	Forager	Collector	Cultivators[1]
Residential Mobility	High	Low	Low
Logistical Mobility	Low	High	High
Diet	Generalized	Specialized	Specialized
Dependence on Storage	Low	High	High
Incongruity of Resources	Low	High	High
Archeological Site Types[2]	R,L	R,L,F,S,C	R,L,F,S,C
Assemblage Variability:			
Residential	High	High	High
Location	Low	Low/High	Low
Field Camp	Infrequent	Moderate/High	Moderate
Station	Infrequent	Low	Low
Cache	Infrequent	Low	Low
Intersite Variability	Low	High	High
Site Visibility:			
Residential	Moderate/High	High	High
Location	Low	High	High
Field Camp	Infrequent	Moderate/High	Moderate/High
Station	Infrequent	Moderate	Moderate
Cache	Infrequent	Moderate/High	Moderate/High

1. Cultivators, in this case, refers to groups heavily dependent on domesticated plants and a storage strategy.

2. Site types R,L,F,S, and C are residential, location, field camp, station, and cache, respectively (Binford 1980).

locations, include field camps, stations, and caches. Food camps are formed when specialized task groups leave a residential camp to procure food resources. The locations of these camps are within the logistical radius of the residential camp. In an arid environment such as the study area, the duration and range of these trips might also be conditioned by seasonal water sources. Stations are defined as locations where these specialized food procurement parties engage in the gathering of information, for example, monitoring of game movements, the planning of hunting strategies, or observing the activities of other humans (Binford 1980:13). Thomas (1983a:85-87) notes the Shoshonean "fandango" as functioning as a "station" in the overall information exchange system.

Food caches are often required when a small task group acquired substantial amounts of bulk resources for the benefit of the larger social group and where transport to the residential camp is not feasible or efficient. Binford (1980:12) also points out that in some cases these bulk resources "serve as the stimulus for repositioning the consumers."

Long-term land use is reflected in the archeological record through "the prolonged accumulation of repeated events" (Foley 1981a:8). "Archeologists still sometimes tacitly assume that a single site must represent a single activity (or, at most, that the major functional focus may have shifted once or twice during the occupational history of that site)" (Thomas 1983a:22). Interpretation of land use through time is, however, complicated by a number of considerations. Binford (1980:9-10; 1982:11-14) has used his knowledge of the Nunamiut Eskimo to point out the redundant use of specific locations for different functions through time. In summary, Binford (1980:12) states: "It should be clear that, other things being equal, we can expect greater ranges of intersite variability as a function of increases in the logistical components of the subsistence-settlement system."

The build-up of material remains of these activities complicates the interpretation of the function of these locations. As Foley (1981a:8) explains:

> Accumulation in the archaeological record is the result of continued exposure of the landscape to occupation, exploitation, and discard, which in turn results in the following effects on the behavioral patterns described above: an increase in the density of material, a blurring of the spatial patterns, and, under some circumstances, a distortion of the behavioral component. Overall, through accumulation the regional archaeological structure is continually reiterated, leaving a richer but less resolved pattern.

For example, Binford (1980:9) points out that as the year to year redundancy in the residential occupation of particular places increases, "the greater the potential build-up of archeological remains," and, of course, the greater the potential for observation on the landscape. Furthermore, locations of resource extraction in an environment where resources are redundantly positioned are those in which we would expect to observe accumulations of artifactual material that reflect a long history of occasional activity. We see, then, that spatial and density patterns of artifacts, as emphasized by Foley (1981a; 1981b; 1981c), are revealing long-term trends in land use and may be of equal or greater significance to our understanding than a few site specific events.

Because of our interest in prehistoric land use in Canyonlands, we devoted considerable attention to mapping the spatial distribution of all artifacts observed during the Island-in-the-Sky survey and excavation project. For many years, archeologists have generally ignored the research significance of artifact scatters in southeastern Utah and elsewhere. The interest in artifact assemblage variability and pattern diversity discussed in a later chapter developed directly from our concern with measuring redundant versus variable activities at given locations on the landscape.

ABORIGINAL FOOD STORAGE

Archeological and ecological investigations of food storage have received considerable attention since our initial research problem statement (Osborn and Hartley 1984) was formulated. Recent studies dealing with food storage that were not referred to in this original document include Ames (1985, 1988), Brenton (1988), Osborn and Vawser (1991), Powell (1987), E.A. Smith (1988), Soffer (1989), Testart (1988), Thomas (1988), Wills (1988), and Wolley and Osborn (1991). A very significant synthesis of evolutionary ecological studies of animal food hoarding has also been

published by Vander Wall (1990). The following discussion of aboriginal food storage does not incorporate this recent material.

In the previous discussion of hunter-gatherer home range and mobility, we described the forager-collector continuum in which "foragers" exhibit high residential and low logistical mobility strategies for mapping consumers onto resource structure; whereas "collectors" depend on high logistical/low residential responses to procurement demands (Binford 1980; Kelly 1980, 1983; D.H. Thomas 1981, 1983a). Mobility strategies, in this case, represent adaptive responses to the spatial/temporal changes in abundance and availability of resources that impose constraints on group size. In a seasonal environment, then, forager group size and regional population densities are ultimately limited by the availability of resources during seasonal lows in production. Seasonal or periodic peaks in resource abundance and availability may be effectively used by hunter-gatherers to meet consumer demands, should local group size and regional population densities increase. Larger, less residentially mobile groups can be maintained if peaks in food production or availability can be exploited in quantities in excess of short-term consumer demands. As Schalk (1977, 1978, 1981) and Binford (1978b, 1980) point out, collectors gain "time utility" from periodically aggregated, storable resources; possession of such an alternative enables collector group size and regional densities to exceed those of a more generalized forager in the same environment (Schalk 1978, 1981).

We should emphasize at this point that the implementation of a food storage strategy is costly with respect to hunter-gatherer time-energy budgets. The forager-collector "dichotomy" reflects a significant shift in selective pressures on hunter-gatherer systems. Schalk (1977:231) points out that, "With storage, then, the locus of potential stress on a cultural system shifts from the point of lowest productivity in the yearly cycle to the period when food is processed for storage." As Hitchcock (1982:295) states, "... a major problem faced by groups which store foods is that they must mobilize labor during a restricted period in order to complete the work of procurement and processing of materials for storage."

Storage facilities and long-term shifts in storage volume have been studied in several cases in the Southwest (e.g., Glassow 1972a, 1972b; Hill 1970; Longacre 1970; Plog 1974; Powell 1983, 1987). Powell (1987), for example, studied changes in storage facility volume at Black Mesa; however, many of the storage facilities in the study area of southeastern Utah are isolated from large residential sites. As a result, it might be more difficult to monitor changes in storage volume through time. Emphasis in this study will be given to investigating the relationships between storage volume and environmental setting (e.g., elevation, vegetative associations, and diversity). Furthermore, we may have the opportunity to investigate resource storage as a component of short-term collecting and long-term foraging strategies.

As we have seen, marked dependence on food storage is correlated with a number of additional aspects of hunter-gatherer behavior (Binford 1978b, 1980, 1983; Schalk 1977, 1978, 1981; Testart 1982). Storage features are relatively conspicuous in the archeological record and can therefore be used to monitor hunter-gatherer mobility, duration of occupation, intersite variability, patterns of long-term land use, and so forth (e.g., D.H. Thomas 1983a:82). More significantly, however, the forager-collector systems lie at either end of a broad range of variability in food procurement and food consumption patterns. We believe that archeological investigations in southeastern Utah will provide an opportunity to examine marked variation in aboriginal food storage systems.

For example, horticulturally-dependent groups occupied relatively permanent residential sites with associated storage facilities; whereas collector groups made use of residential locations where food stores were kept in addition to more distant stores and caches. Southeastern Utah may also enable us to examine yet another variation of food storage in which residentially mobile foragers moved through environmental patches during seasonal or periodic highs in production and stored food resources in isolated masonry cists. The same groups would then return to these food stores during periods of low food availability. This kind of food storage system may not have been observed in ethnohistoric contexts.

Sharrock and Marwitt (1967) describe four kinds of storage facilities constructed by aboriginal groups assigned by archeologists to the "Fremont culture." These storage features include: 1) unlined pits; 2) slab-lined pits or cists; 3) above-ground masonry granaries; and 4) coursed adobe granaries (Sharrock and Marwitt 1967:42-43). Unlined pits are either associated with

habitation sites or activity areas and may be capped with clay. Slab-lined cists are most frequently found in cave or shelter floors; these storage features were often roofed with poles, thatch, and mud plaster. Above-ground masonry granaries are also found in caves or overhangs from southern Wyoming to the Fremont drainage (Sharrock and Marwitt 1967:43). These masonry structures generally seal off small crevices and overhangs and may be beehive-shaped, circular, or semi-circular. These storage features may be roofed with poles, thatch, plaster, and/or stone slabs and are accessed either through the ceiling or the side walls. Finally, Fremont sites may have relatively large free-standing coursed adobe granaries which measure six by twelve feet and may stand more than four or five feet tall (Sharrock and Marwitt 1967:43). Similar granaries may also be attached to the outside walls of Fremont houses. Such coursed adobe granaries are most generally found at Sevier-Fremont sites of west-central Utah. Recent archeological surveys in Canyonlands have revealed a number of isolated above-ground masonry structures like those described by Sharrock and Marwitt (1967). These will constitute part of the storage features that will be examined during the course of work outlined in this research design.

There is an additional aspect of food storage strategies which we would like to point out at this time. Logistically-organized hunter-gatherers (i.e., collectors), as well as horticulturalists, practice a specialized or coarse-grained exploitative strategy. Wiens (1976) describes the heterogeneity of resources in an environment in terms of their abundance and availability in space and time. Organisms that exploit such resources in roughly the same proportions in which they are available are said to be generalists (fine-grained response); whereas organisms that exploit resources disproportionately are referred to as specialists (coarse-grained response). Schalk (1977:229) states, "Food storage is a mechanism for not exploiting resources in proportion to their natural availability in the environment, and increased storage implies increased specialization."

In relatively low-latitude environments we know that most specialized human diets are based on plant products. Plants generally represent aggregated, renewable, and high-energy-yielding food resources; such characteristics, in addition to storageability, are essential for specialized feeding strategies in areas without herd animals or anadromous fish. Unlike animal products, plant resources generally require little processing prior to storage; however, plant processing costs are frequently high, and considerable time and energy must be devoted to food preparation prior to consumption. This investment may be distributed evenly throughout the storage period.

Existence of food storage also suggests that aboriginal groups may be subject to nutritional deficiencies. We know that specialized diets based on plant resources may lead to nutrient shortages and imbalances, as well as increased threat from phytotoxins and mycotoxins (Abrams 1979; Behar 1968; Blakely 1971; Cassidy 1980; El-Najjar and Robertson 1976; El-Najjar et al. 1976; Jackson 1991; Johns 1990; Lallo, et al. 1977; Liener 1980).

We might then expect to observe archeological and osteological evidence for aboriginal dependence on more specialized diets and food storage in this region of the Southwest and the Colorado Plateau. The second portion of the land use chapter examines the significance of ungulate herds and supplemental plant food storage for prehistoric overwintering strategies on the Colorado Plateau. Specific attention is also given to important aspects of both ungulate and human physiology and nutrition. These biological factors are critical to our understanding of variability in aboriginal food storage strategies.

PREHISTORIC NUTRITION, HEALTH AND DEMOGRAPHY

Reviews of contemporary research in paleonutrition, paleopathology, and paleodemography reveal the tremendous potential for human osteological analysis to solve anthropological and archeological problems (e.g., Buikstra and Cook 1980; Cohen and Armelagos 1984; Haas and Harrison 1977; Russ-Ashmore et al. 1982; Wing and Brown 1979). Many of these recent developments in paleonutrition and paleopathology had not been applied to problems in the American Southwest, or their results were not yet published when we began our research. Since the initial development of our research in southeastern Utah, archeologists and physical anthropologists have carried out several very provocative studies involving prehistoric diet, nutrition, and health (e.g., Berry 1983; Decker and Tieszen 1989; Matson and Chisholm 1991; Merbs and Miller 1985; Spielmann, Schoeninger, and Moore 1990; Stodder 1987; Wetterstrom 1986).

Much of the work in paleonutrition and disease has focused on the shift from hunting and gathering to horticulture. There is now considerable empirical evidence for a number of nutritionally-related changes in physiology and morphology which are manifest in human osteology (see Cohen and Armelagos 1984). Unlike our traditional "neolithic revolution" views of horticulture involving food security, improved health, and increased leisure time, we are forced to see the origins of agriculture in a new light. Flannery (1969:86) has pointed out, "There is no reason to believe that the early food producers were significantly better nourished than their food collecting' ancestors. Nor was their subsistence necessarily more 'reliable'..." Recent paleonutrition and paleopathological research has most certainly substantiated Flannery's expectations. Furthermore, the investigations of Binford (1983a), Boserup (1965), Clark and Haswell (1967), and others have revealed that increased reliance on agriculture is a function of labor intensification or more work per unit return. And, increased dependence on plants, including agriculture plants, requires considerable investments of processing time and technology (e.g., Abrams 1979; Hawkes and O'Connell 1981; Hayden 1981). If we are to gain a better understanding of horticultural adaptations we must recognize that greater use of domesticated plants (and animals) required certain tradeoffs between increased local production versus increased risks (e.g., climatic perturbations, resource depression, nutritional disorders, and disease).

Growth Patterns and Stature

Several nutritional disorders and synergistically-related diseases are evident in human skeletal remains. Changes in caloric and nutrient intake may be reflected in terms of fluctuating growth rates. For example, periodic availability of calories and/or high-quality protein for prehistoric populations may be expressed in terms of increased frequency of Harris lines and decreased cortical bone thickness (e.g., Buikstra 1981; Cassidy 1980; Clarke 1978; Cook 1971, 1976, 1979, 1981). Cook's (1971, 1976, 1979, 1981) investigations of prehistoric horticulturalists in west-central Illinois reveal that increased dependence on maize can be observed as changes in Harris line frequencies and in decreased cortical thickness of long bones.

A number of investigators working in both the Old World and North America and Mesoamerica have found correlations between increased reliance on agricultural foods and decreased body size, i.e., stature reduction (e.g., Angel 1946a, 1946b, 1971, 1975; Haviland 1967; Larsen 1982; Nickens 1976; Saul 1972; Stewart 1949, 1953). Similar trends in body size have been observed among contemporary populations throughout the world, involving increased dependence on carbohydrate foods and decreased availability of high-quality protein (e.g., Frisancho, Garn, and Ascoli 1970a, 1970b; Frisancho et al. 1973; Garn and Clark 1975; Garn and Frisancho 1971; Garn, Nagy, and Sandusky 1972; Martorelli et al. 1979; Stini 1969, 1971). Albanese and Orto (1964) describe reductions in body size that are specifically related to increased consumption of maize.

Cranial Morphology, Dentition, and Dental Health

Marked changes in cranial morphology have been observed to occur during the shift from meat diets to plant diets (e.g., Carlson 1974, 1976a, 1976b; Carlson and Van Gerven 1977, 1979; Van Gerven et al. 1977; y'Edynak 1978, 1980).

In turn, modifications in human dentition have been causally linked to these observed orofacial/cranial changes which reflect diet composition and food preparation technology (e.g., Brace 1978; Brace and Hinton 1981; Brace and Mahler 1971; Brace and Ryan 1980; Larsen 1982; Sciulli 1979; Smith, Smith, and Hinton 1980). In general, such dental changes represent decreased tooth size. Larsen (1982) found that tooth size reduction took place during the transition from hunting and gathering to horticulture on St. Catherine's Island, Georgia. However, tooth size reduction only characterized the adult females, suggesting that there was greater sexual dimorphism among the later horticultural population.

There are several other significant changes in dentition that characterize hunter-gatherer versus horticultural groups. Brace (1962) suggested that the intensive use of grinding stones on grains and the appearance of pottery in the Neolithic are associated with a substantial reduction in food toughness. The change from a hunter-gatherer subsistence to a diet based on ground grains and food cooked in water should produce

a reduction in food toughness, fibrousness, and resistance, and thus a reduction in the role of the teeth in breakdown of foods. The product of this change in food consistency, Brace argued, was a change from flat molar wear to a more oblique wear pattern.

Smith (1984) found that it was possible to differentiate between groups of hunter-gatherers and agriculturalists based on molar wear plane angles. Smith (1984) included crania and mandibles from Gran Quivira or Pueblo de las Humanas in central New Mexico. Smith (1984:54) states that, "Agriculturalists show a more restricted pattern of wear and tend to develop oblique wear planes ... [attributable] to a reduction in food toughness or fibrousness ... [and] the appearance of intensive collection of grains and intensive use of grinding stones and pottery in food preparation."

Dental abnormalities associated with the adoption of agriculture also include increased frequency and severity of caries (e.g., Armelagos 1969; Armelagos and Rose 1972; Corbett and Moore 1976; Moore and Corbett 1971, 1973, 1975, 1978). Turner (1979) points out that dental caries increase with increased consumption of domesticated plants. Caries rates are: hunter-gatherers (1.3%); mixed diet-agriculture, hunting, fishing, and gathering (4.4%); and agriculturalists (8.6%) of all teeth were carious. Larsen (1982) argues that the observed increase in caries for later aboriginal populations (A.D. 1150-1500) on St. Catherine's Island, Georgia, is attributable to increased consumption of maize. This conclusion is supported by additional investigations (e.g., Anderson 1965, 1967; Cook and Buikstra 1973, 1979; Hooton 1930; Larsen 1982: Newman and Snow 1942; Smith 1984; Stewart 1931, 1943, 1949, 1953; Ubelaker 1981).

Larsen (1982:220-21) states,

> The single most likely explanation for the significant increase in dental caries on the prehistoric Georgia coast is related to the nature of the food staple forming the economic basis of the agricultural lifeway: corn. The progressive dependence on this dietary carbohydrate most likely promoted the growth of odontolytic organisms in the dental plaque of the agricultural group. Corn has a high sucrose component and it has been shown that low protein and high sucrose diets predispose teeth to the growth of cariogenic organisms (Rowe 1975).

In addition to these aspects of dental change and diet, human teeth also provide information regarding interruptions in growth patterns. Enamel hypoplasia, evidenced by horizontal bands and grooves on the outer surfaces of teeth, indicates disruption of metabolism; hypoplasia has been shown to be correlated with increased dependence on agriculture (e.g., Cassidy 1980; Cook and Buikstra 1973, 1979; Falin 1961; Larsen 1982; Rose et al. 1978; Saul 1972).

Porotic Hyperostosis and Periosteal Reactions

A number of studies in paleopathology have addressed the subject of porotic hyperostosis, which refers to "abnormal bony changes in the skull appearing as spongy bone or sieve-like porosity in the cranial bones and/or orbits" (El-Najjar 1976:329). In the Old World, a similar pathological condition is associated with malaria, sickle-cell anemia, G6PD deficiency, and thalassemia (Angel 1966; Baker 1964; Caffey 1937, 1939; El-Najjar 1976; Mensforth et al. 1978; Moseley 1974; Russ-Ashmore et al. 1982).

In the New World, porotic hyperostosis has been causally linked to heavy dependence on agricultural staples, particularly maize (Carlson et al. 1974; Cassidy 1980; Cybulski 1977; El-Najjar 1976; El-Najjar, Lozoff, and Ryon 1975; El-Najjar, Ryan, Turner, and Lozoff 1976; El-Najjar and Robertson 1976; Eng 1958; Hengen 1971; Kuntz and Euler 1972; Lallo et al. 1977; Mensforth et al. 1978). Several investigators have questioned the causal linkages between maize consumption, iron-deficiency anemia, and porotic hyperostosis (e.g., Kent 1986; Reinhard 1988).

El-Najjar (1976) and co-workers examined 3,361 human crania from the New World, including specimens from Chaco Canyon (32), Gran Quivira (177), Navajo Reservoir (92), Inscription House (24), and Hopi (189). Excluding the Hopi adult group, porotic hyperostosis was more frequent in the entire sample among maize-dependent populations than non-maize consumers. El-Najjar and others have argued convincingly that porotic hyperostosis occurs in maize dependent

groups in greater frequency, due to the inhibitory effects of corn on the bioavailability of iron. This nutritional deficiency is further exacerbated by low animal protein intake, intestinal parasites, and prolonged breastfeeding (El-Najjar 1976; Lallo et al. 1977; Mensforth et al. 1978). High infant mortality due to iron deficiency anemia is indicated in the Late Woodland ossuary remains at the Libben site in Ohio, where frequency of porotic hyperostosis increases and peaks in the 1-3 year old category (Mensforth et al. 1978). This nutritional problem is currently one of the most significant causes of infant mortality in underdeveloped nations. Mensforth et al. (1978:12-13) state, "Modern epidemiological studies demonstrate that iron-deficiency anemia is so prevalent throughout the world that it is now regarded as an excellent index of the nutritional health of a population."

Periosteal reactions are caused by a number of diseases, including pulmonary hypertrophic osteoarthropathy, hypervitaminosis A, infantile cortical hyperostosis, and thyroid acropachy (Mensforth et al. 1978:8, Table 2). Periosteal reactions result in the elevation of bone surfaces or lesions which are most frequently found on the surfaces of long bones. Such lesions are frequently associated with porotic hyperostosis and are thought to reflect synergistic relationships between nutritional disorders and infectious disease (Mensforth et al. 1978:12).

In the New World, however, many instances of periosteal reaction appear to be linked again to maize consumption (Cassidy 1980; Cook 1976; Mensforth et al. 1978). Higher population densities of maize horticulturalists and more sedentary lifestyles may be seen as ultimate causes for periosteal reactions; at the proximate level of analysis, we might see iron deficiencies caused by pathogens, the inhibitory effects of maize and lower animal protein consumption, bacterial infections, and weanling diarrhea (El-Najjar 1976; Mensforth et al. 1978; Russ-Ashmore et al. 1982). Mensforth et al. (1978:38) found periosteal reactions and porotic hyperostosis to be significantly correlated on an age-specific basis for infants (6-12 month and 12-24 months). They (1978:38) state,

> The age-specific correlation in the 6 to 24 month age class corresponds to the known age at which iron-deficiency anemia reaches its highest frequency among infants and children. The [age-specific] distribution of the pneumonia and weanling diarrhea syndrome has been implicated as the leading cause of infant and child mortality in industrial and pre-industrial societies (Gordon et al. 1963).

Demography

Prehistorians working in the American Southwest have long expressed an interest in prehistoric population (e.g., Colton 1932, 1936, 1949, 1960; Cordell 1975; Euler 1988; Gumerman 1969, 1975; Hack 1942; Hayes 1964; Leonard 1989; Longacre 1970; Orcutt 1974; Plog 1974; Powell 1988; Schlanger 1987, 1988; Swedlund and Sessions 1976; Turner and Lofgren 1966; Gumerman 1969, 1975; Wetterstrom 1986; Zubrow 1976). A number of indices have been utilized by archeologists in order to assess relative changes in prehistoric population size through time, including bowl-to-jar volume ratios (Nelson 1981; Turner and Lofgren 1966), site length (Hack 1942), room number and size (Hill 1970; Longacre 1970), number of rooms and area of rubble (Plog 1974), site frequency (Schwartz 1956), and so forth.

Frequently, prehistoric population curves are compared with climatic and other environmental changes in attempts to reconstruct the dynamic aspects of aboriginal life (e.g., Cordell 1975; LeBlanc 1978; Plog 1974; Swedlund and Sessions 1976; Zubrow 1975). In a number of cases, archeologists in the Southwest have used such population estimates to describe patterns of local and region migration rather than to examine basic processes of demography related to changes in fertility and mortality. Prehistoric migration is not only the primary reason many offer for local/regional fluctuations in population size, but it is also one of the major normative-based "causes" for observed variations in artifacts, architecture, and settlement.

We have chosen to examine prehistoric demography in southeastern Utah and adjacent areas in terms of infant mortality, birth spacing, and nutritional stress. Binford and Chasko (1976) have investigated several significant factors (i.e., diet, mobility, and male absentism) involved in the "demographic transition" accompanying the shift from residential mobility to sedentism for the Nunamiut Eskimo in Anuktuvak Pass,

Alaska. Ethnographic research and computer simulations reveal that increased population growth rates associated with a reduction in mobility are a result of increased live birth rates, rather than decreased mortality rates due to improved nutrition and medical care.

Infant mortality rates, then, are an essential variable which must be monitored in order to better understand changes in human population growth in the present or past. Lallo and Rose (1979:325) state, "Well-documented epidemiological studies have demonstrated that infant and child mortality has such a profound influence on the crude death rate of a population, that it has become accepted as a measure of population fitness (Gordon et al. 1967)." Numerous studies in international health and nutrition utilize infant mortality rates as a meaningful measure of adaptive success for human populations (e.g.,Adamchak 1979; Ekanem 1972; Hauser 1959; Institute of Medicine, National Academy of Sciences 1973; Stockwell 1966).

Infant mortality rates have been used in several preliminary investigations of prehistoric health and demography (e.g., Clarke 1980; Cook 1979; Cordell 1980; Lallo and Rose 1979). Osteological samples from southeastern Utah in and of themselves will probably not be adequate for estimating actual infant mortality rates. However, emphasis will be given to mortality "profiles"and corresponding evidence for stresses on population involving nutrition and disease. Buikstra and Cook (1980) point out that infant and child remains have generally been overlooked or neglected by paleopathologists. Nickens (1982:99), for example, states,"From the table it can be observed that just over 150 human burials from southeastern Utah have been described in detail; however, a significant number of these are poorly preserved materials or infants, situations which negate many meaningful observations."

In the previous discussion of nutritional disorders, for example, infant mortality rates were causally linked to iron-deficiency anemia, parasites, and weanling diarrhea. Iron-deficiency anemia and weanling diarrhea have been linked to societies in which dietary dependence on maize is high (El-Najjar 1976). And Buikstra and Cook (1980:447) state,

> Several studies indicate that prehistoric agriculturalists in the New World were more vulnerable to stress during childhood than earlier, less specialized groups living in the same region (Cassidy 1980; Rose 1977; Sciulli 1977, 1978). Although this trend is not apparent in the data reported by Cook and Buikstra (1979), their data do support selection against affected individuals during the weaning period in groups dependent upon maize agriculture.

Increased dependence on maize horticulture in the American Southwest should, therefore, be reflected in the archeological record by increased infant mortality. Death rates increase in this age group due to nutritional disorders resulting from nutrient deficiencies arising during weaning (e.g., Clarke 1980; Cook 1979; El-Najjar 1976; Gopalan and Srikantia 1973; Haas and Harrison 1977; Lallo and Rose 1979; Mensforth et al. 1978; Rose 1979; Scrimshaw 1964). In many agricultural societies infants are weaned early and their solid food diet is one characterized by high carbohydrate-low protein cereals (Scrimshaw 1964). Frequently, infants are shifted from breastfeeding to solid foods in order to free the mother from child care and to enable her to return to gardening activities (Ember 1983; Nerlove 1974). In turn, termination of breastfeeding results in the exposure of the female to the risk of another pregnancy (Haas and Harrison 1977:88; Roth 1981). As Roth (1981:420) points out, infant death, and early weaning have a pronounced effect on human population growth rates:

> Preston (1978) has recently called attention to the relationship between infant/juvenile mortality and fertility levels in populations which feature breastfeeding. The death of an infant in these groups initiates a cessation of maternal lactation, which in turn has been shown to shorten postpartum amenorrhea (Knodel, 1968: Van Ginniken, 1978). The effect of a mortality decline upon birth spacing may well be actual lengthening of these intervals, as improved offspring survivorship leads to completion of the total breastfeeding period, and hence a delay in the resumption of ovulatory cycles and further pregnancy.

The relationships between nutrition, disease, and demography are complex; yet it is through such complexity that investigators can begin to monitor a number of very crucial aspects of prehistoric life in southeastern Utah. Bioarcheologists should take advantage of the information represented by infant and child burials in this region. Increased rates of population growth may be reflected archeologically in terms of increased infant mortality. Such high mortality rates in turn power increases in fertility rates. Increased dependence on maize horticulture should be expressed in higher infant mortality in the 1-3 age class, increased frequencies of periosteal reactions and porotic hyperostosis among the 6-24 month age class, and greater incidence of Harris lines and enamel hypoplasia in children. One should also expect to observe increased fertility rates measured as a function of early weaning and a shortening of birth spacing. Shifts in the age of weaning for infants may be monitored through use of trace element analysis based on strontium/calcium ratios. Sillen and Kavanagh (1982:75) state,

> ...it may be possible to gather an entirely new range of paleodemographic data by estimating the age of weaning, or at least the age of dietary supplementation with solid foods. The observations that (a) the Sr/Ca ratio of milk is generally very low; (b) the Sr/Ca content of cereal foods (gruel) is generally very high; and (c) the turnover of strontium and calcium in growing skeletons is vary rapid, suggests that, if children's skeletons could be accurately aged by conventional physical anthropological techniques, a dramatic shift in Sr/Ca ratios at a particular age could be interpreted as due to weaning.

Use of trace element analysis as well as carbon isotope analysis ($^{13}C/^{12}C$) in the American Southwest may prove to be quite effective in this study of weaning age, especially for maize dependent populations (Buikstra and Cook 1980). It is during the agricultural period(s) that we expect to observe a decrease in the birth spacing as a function of early weaning.

Another particularly interesting aspect of strontium analysis involves frequency of pregnancy for particular females. Sillen and Kavanagh (1982:75) point out that, "Placental tissue discriminates against strontium in the transfer of alkaline earths to the fetus ...." As a result, infants contain exceptionally low Sr/Ca ratios; whereas adult females exhibit characteristically higher Sr/Ca ratios than adult males (in primitive populations). Such disparities in adult Sr/Ca ratios may provide us with a relative measure of the time adult females spend in pregnancy and lactation. Initially, we might expect this Sr/Ca ratio disparity to be greater for later populations of adult females and males in maize dependent groups than for earlier non-horticultural groups. This remains to be investigated in the archaeological record.

ABORIGINAL ROCK ART IN UTAH

The following discussion of prehistoric rock art was initially developed as a research problem to be investigated in the national monuments, recreation areas, and parks in southeastern Utah (Osborn 1984a, 1984b; Osborn and Hartley 1984; Osborn et al. 1986). Although prehistoric rock art has been documented in the Island-in-the-Sky District of Canyonlands National Park, none was recorded during the road survey project on the Island. This research design was elaborated upon and empirically evaluated by Baumann (1989) for 15 Davis Canyon sites and by Hartley (1989, 1991, 1992) for 388 southeastern Utah sites. These significant analytical studies should be consulted for thorough literature reviews, analytical methods, and conclusions. The remainder of this section presents a condensed version of the original discussion of an ecological approach to the study of prehistoric rock art.

Prehistoric rock art has captured the imagination and interest of laypersons and archeologists and is among some of the most readily recognizable remains in the archeological record. Traditionally, such paintings and engravings have been thought to reflect the casual "doodlings" of individuals or the attempts of past hunters to conduct sympathetic magic in order to effect a successful hunt. Recent investigations suggest that prehistoric rock art throughout the world possesses considerable information regarding time reckoning, related astronomical phenomena, fertility "cults," and

local/regional "style" zones (Edwards 1971; Leroi-Gourham 1968; Lewis-Williams 1981; Marshack 1972; Woodhouse 1979).

Aboriginal rock art constitutes one of the major components of the archeological record of the Great Basin and the American Southwest regions. Rock art —both pictographs and petroglyphs—constitutes perhaps one of the most systematically documented aspects of the archaeology for the national parks, e.g., Arches, Canyonlands, Natural Bridges, and Glen Canyon in eastern Utah (Baumann 1989; Hartley 1989, 1991, 1992).

Anthropologists and archeologists have recently focused their interest on language and art as components of an information management system that is critical for human adaptive responses to the environment. Until quite recently, aboriginal rock art had not been examined in a rigorous, scientific manner. This discussion will define the interrelationships between aboriginal "art," information, and human adaptive responses to arid environments.

Recently, a number of investigators have emphasized the significance of information as a variable relevant to the character of human adaptive responses (e.g., Conkey 1978, 1980; Flannery 1972; Gall and Saxe 1977; Johnson 1978, 1982, 1983a, 1983b; Moore 1977, 1978, 1981a, 1981b; Pollock 1983; Root 1983; Wiessner 1983; Wilmsen 1973; Wobst 1974, 1977). Information in these studies is viewed as a critical resource and is equated with knowledge about the environment, biophysical and social. Many of these anthropological investigations assume that information is essential for the decision-making connected with resource acquisition and for adjusting producer capabilities to consumer demands. As Moore (1981b:194-195) states, "As an all-knowing, computationally perfect decision maker, the 'economic man' serves the useful modeling function of holding the informational capabilities and capacities constant while the dynamic created by variations in the flows of matter and energy is investigated."

Ecologists, including Margalef (1958, 1963, 1968), Patten (1959), and others, have proposed that information is a characteristic of ecological systems which is systematically linked to energy flow and the development of ecological structure or organization. Information is thus a function of the shifts in the ratio of production-to-biomass (P/B) throughout ecological succession. Information, as used in ecological theory, refers to "a posteriori restrictions of a priori probabilities" (Margalef 1968:2). Simply put, this means that the existing structure and dynamic relationships within an ecosystem (or any cybernetic system) imposes constraints on the probability of future events or outcomes within the system. The more organizationally complex systems contain a greater number and diversity of constraints so that future system states are more readily anticipated. In such cases, ecologists speak of higher information content within the system.

As Margalef (1968:12) emphasizes, it is probably not necessary to speak of "stability" within systems, but rather we might view increased diversity, organizational complexity, and information as the concomitants of decreased "frequency of fluctuations" both within and outside the system. In the context of human food-getting strategies, then, we might anticipate that increased levels of information flow might be linked to demands for decreasing the "frequency of fluctuations" in producer capabilities to meet consumer demands. Such relationships between increased information and increased stability in food-getting activities could then be seen as efforts to minimize risk.

Such increased levels of information in human adaptive systems exhibit greater costs associated with information acquisition, storage, transmission, and decoding (if necessary). In many cases, such increases in information costs are associated with the diversion of greater and greater amounts of time and energy away from direct producer activities. Information "brokers," e.g., headmen, shamans, "sun priests," "garden magicians," and curers, must be subsidized through the reallocation of time and energy budgets of productive individuals. Such increased information costs would not only demand organizational changes in societies as described above, but also investments in the elaboration of structure, e.g., development of languages, codes, symbols, mnemonic devices, message sticks, calendrics, counting systems, portable and nonportable art, and/or writing.

Margalef (1968) suggests that information is stored in the environment in the form of inanimate objects and features such as dead vegetal material, animal burrows and paths, shells, and territory markers. Information is also contained in or expressed by such things as animal spores, carcasses and faunal remains, geological features, as well as the archeological record of

geological features, as well as the archeological record of past human behavior. Aboriginal populations would have had ready access to information regarding the presence of both animals and other human groups within given areas of land. Human tracks, paths, and previous activity areas—including hunting stands, kill sites, processing camps, and residential locations—would, no doubt, be utilized as information sources about the presence of other human groups. It is also expected that further information regarding human activity might be conveyed through more deliberate means such as rock art. Such information would be expected to supplement the "archeological record" used by aboriginal populations and would transmit messages not readily obtained directly from material remains. We are not suggesting at this point that rock art was originally meant to convey a message to others. The appearance of rock art and/or its modification would provide aboriginal groups with information about the occupation or use of foraging and hunting areas.

Information regarding the presence of potential competitors is essential for the implementation of foraging strategies among human foraging groups, as well as for collectors and food-producing groups who make use of more distant areas of their home range for acquiring essential resources. Information regarding other populations who might be or who were utilizing given resources would facilitate decision making regarding optimal patch choice, optimal diet, time allocation, and optimal mobility tactics. Such information would serve to minimize risks associated with procurement of critical resources.

Humans are expected to implement adaptive strategies based on substantially more information about the environment than other species. In turn, we might also expect to observe both qualitative and quantitative differences in information between human groups organized at different levels of sociocultural complexity (e.g., Athens 1977; Gall and Saxe 1977; Johnson 1982, 1983b; Moore 1981a, 1981b). Such qualitative and quantitative changes in information potential in human societies are expected to be associated with the development of adaptive contexts exhibiting greater levels of risk (e.g., increased population densities, dietary specialization and adoption of food storage, food redistribution, and warfare).

Rock art most probably has served as a means of conveying information to individuals and to groups that serves to enhance their chances for survival in a high-risk environment characterized by low plant productivity, unpredictaable precipitation, and patchy resource distribution. The concept of information is quite relevant in our investigations of prehistory in eastern Utah, for it serves to unify a number of seemingly disparate aspects of the archeological record, e.g., ecological structure and dynamics, human foraging behavior, subsistence specialization and food storage, and aboriginal rock art.

Information Content of Rock Art

Traditionally, anthropologists have conducted investigations of human behavior, relying on one of two diametrically opposed perspectives: the emic and the etic approach. The emic approach involves an attempt by the anthropologist to discover the rules and cognitive categories possessed by the cultural member or individual; whereas the etic approach is based on a systematic test of the anthropologist's explanations or ideas about human behavior. As Harris (1983) points out, the etic perspective may involve the association or juxtapositioning of factors or categories that the actual cultural participants find counterintuitive or meaningless.

The information content of rock art panels can be expressed in terms of the Shannon information statistic. The average information content width may be expressed in one of the following form:

$$H' = -\Sigma\ p_i \log_2 p_i$$

(where H' = information content per individual
p_i = the proportion of the ith category).

This expression of information content has been utilized by ecologists to measure species richness or diversity (Margalef 1968; Pielou 1975), as well as by archeologists to quantify archeological assemblage variability (Osborn 1977, 1979; Reher 1977; Saxe 1970; Tainter 1975; Wood 1978; Yellen 1977). This measure seems particularly appropriate for our analysis of the prehistoric rock art in eastern Utah since one of our basic assumptions is that such archaeological features served within a broader context of aboriginal land use, e.g., repositioning strategies, scheduling of resource use, and boundary maintenance or territoriality. Furthermore, such a measure of information can also be

utilized to quantify environmental variability, as well as archeological assemblage variability. These measures may then all be used in correlational analyses designed to evaluate our ideas and explanations of rock art function, diversity, and distribution.

Several additional information measures may be calculated for the rock art panels in southeastern Utah. Such measures are thought to offer additional analytic dimensions that might be of use in an examination of aboriginal rock art in this region. One measure, H_{max}, refers to a value for the maximum information content of the rock art panel based on the total number of glyph categories present. The degree to which the observed information content (H') of the panel matches the maximum information content (H_{max}) can be expressed as a measure of evenness (J). This measure of evenness (J) was suggested by Pielou (1966a) to indicate the degree of heterogeneity or homogeneity in species distributions within ecosystems. As the value of J approaches unity (1.0) one expects to observe maximum diversity and maximum heterogeneity . The minimum value for information (H_{min}) can be calculated for an assemblage or a rock art panel utilizing an expression based on factorials of total numbers of glyphs (N) on the panels. Minimum values of information can then be substituted into a calculation of information redundancy offered by Margalef (1957) and Patten (1962). This value of redundancy in the information "channel" or the rock art panel may prove to be of great significance in our investigation.

Expectations Regarding Aboriginal Rock Art

An explicit assumption in this approach to the study of aboriginal rock art in eastern Utah is that such prehistoric features served to convey information regarding aboriginal land use patterns. Although this rock art may have served within a ceremonial, magico-religious, and/or aesthetic context in past aboriginal societies, recent research has focused on the possibility that rock art possessed information regarding resource distribution and abundance, as well as information about scheduling and repositioning strategies and territoriality.

One can begin to generate explicit expectations concerning rock art in terms of information content variability and resource structure as it would relate to inclusion or exclusion of human groups in land use rights. A model of human territoriality has been offered by Dyson-Hudson and Smith (1978) that may serve initially in the formulation of hypotheses regarding rock art and resource character in this region. They argue that humans, as well as other organisms, will exhibit territorial behavior with respect to resources that are economically defendable, when the benefits of defense outweigh the costs or risk involved. Dyson-Hudson and Smith (1978) suggest that predictable and aggregated resources possess greater economic defendability. One might then expect to observe a continuum of information transmission from high to low as groups shift from open land use systems and information sharing toward more closed systems based on territoriality and boundary maintenance.

Given this model of human territoriality constructed by Dyson-Hudson and Smith (1978), one might suggest that aboriginal groups in southeastern Utah would have utilized rock art in at least two significantly different ways. First, if populations were dependent on foraging strategies, rock art would serve to convey information regarding resource distribution and abundance. Rock art panels may, in fact, have been produced in order to simply record hunting and gathering successes or trips. From an etic perspective, however, such information recorded in the panels could have served to remind the groups about how frequently they have exploited a particular area. Or, other foraging groups may have been able to use such evidence in order to make decisions about expected return rates in certain hunting and gathering areas. It should be emphasized that we are not arguing that rock art served as "billboards" for aboriginal groups; rather we are suggesting that much rock art may have functioned as signs of human activity in the area analogous to encountering "dead" campfires, remains of butchered animals, and spent rifle cartridges by present day hunters.

If rock art functioned in this manner for foragers we would expect to observe low redundancy and high information content for panels associated with generalized hunting and gathering. This kind of rock art would serve to share information among groups, so that risks of foraging in certain over-exploited areas would be reduced. This would be particularly advantageous if these groups were not able to participate in face-to-face social interactions.

On the other hand, rock art may have functioned among collectors and horticulturalists in a much

different way. We might expect that more specialized exploitation of plant resources would enable aboriginal populations to reduce their residential mobility and to collapse their home range size. Increased regional population densities and reduced residential mobility would be expected to increase competition between groups for access to critical resources obtained through logistical mobility. One would see groups making more intensive use of abundant, aggregated, and predictable food resources; this would favor territoriality (Dyson-Hudson and Smith 1978). Rock art under such conditions might then be used to demarcate group boundaries and to define access rights to critical resources. In this case, rock art panels would exhibit high redundancy ("No Trespassing" signs) and low information.

SYNTHESIS AND SIGNIFICANCE OF RESEARCH PROBLEMS

The archeological record of southeastern Utah is complex and cultural resources are abundant and significant. We have chosen the four research problem areas, i.e., aboriginal land use patterns, food storage, paleonutrition-pathology-demography, and aboriginal rock art for four primary reasons: (1) these problems are comprehensive, in that they span the time depth and the range of past adaptations reflected in the region's archeological record; (2) the research problem areas reflect major concerns of contemporary archeological and anthropological research; (3) these problem areas serve to further elucidate specific regional archeological questions within the Colorado Plateau; and (4) investigation of these research problems will facilitate cultural resource management, including inventory and assessment, preservation, evaluation, and interpretation of resources within the national parks.

The problem areas chosen cover seemingly different aspects of past human behavior and archeology. Yet, all four problem areas are closely interrelated in terms of past adaptive behavior patterns. Each topic has been discussed in detail; however, the underlying relationships between aboriginal land use, food storage, nutrition-disease-demography, and rock art may not be readily apparent. As was mentioned previously, one of the major distinctions between aboriginal foraging and collecting adaptations is the food or resource storage that characterizes logistically-organized groups of collectors (Binford 1980; Kelly 1980, 1983). Considerable variability characterizes hunting and gathering societies throughout the world so that this simple dichotomy is in actuality a variable continuum. We might expect, then, to see foragers who practice storage and/or collectors who continue to forage.

Binford (1980), Kelly (1980, 1983), and Thomas (1983a) have pointed out that food storage features have relatively high visibility in the archeological record. This high visibility is due primarily to the high bulk character of storable food resources and the quantities that were required to deal with overwintering strategies in seasonal environments. Such storage features provide us, then, with added insights into the nature of other components of aboriginal adaptations, including degrees of mobility (residential versus logistical). In the initial forager-collector continuum we find that residential mobility declines, whereas logistical mobility increases, as a function of growing dependence on stored foods. Isolated above-ground masonry structures like those found in southeastern Utah take on added significance for archeology given these anthropological arguments. Such archeological features have been noted, yet little has been done with these small, limited-activity sites which often offer few artifactual remains.

We have also learned that increased dependence on agricultural resources, particularly maize, frequently results in decreased viability of human populations and increased reproductive costs, due to high infant mortality rates. Archeologists working in the American Southwest have expressed great concern for operationalizing measures of prehistoric population growth or decline due to out-migration. Marked periods of growth correlate roughly with the advent of horticulture, and many have viewed such change as either the result or the cause of more specialized human diets. Recent studies in nutrition and demography have revealed that these two variables are inextricably and causally linked. Somewhat paradoxically, we see that aboriginal horticulture enabled more food to be produced locally and higher population densities could be supported; yet, a shift toward greater reliance on maize production led to increased stresses related to poor nutrition, increased infectious disease, and perhaps greater parasite loads. In turn, higher infant mortality rates associated with these added health problems powered higher fertility rates. Recent bioarcheological studies have begun to examine not only physical evidence for increased dependence on maize horticulture but also dietary variation based on bone chemistry. Such dietary indicators can also be

"fine tuned" in order to isolate aspects of human reproduction, including the changes in the age of weaning and the length of the female's reproductive career. In this way archeologists will be able to monitor prehistoric and historic shifts in fertility rates (recruitment) and infant mortality rates, which will correlate with demographic change in the region.

Finally, we know that aboriginal rock art will provide an incredibly rich and, as yet, untapped source of information regarding aboriginal land use patterns throughout time and space. Regardless of their originally intended "emic" functions, rock art served as a means of conveying information regarding foraging decisions, territoriality, and resource access rights. If such "art" is translated into measures that express potential information content, aboriginal rock art will reflect patterns that include low redundancy, high information content panels used by foraging groups to share information about resource availability, and high redundancy, low information content artwork that served collectors and horticulturalists in demarcating group boundaries and/or territories. These patterns will, in turn, be related to aboriginal land use patterns, food storage, and shifts in prehistoric demography.

The research problems identified here are presented as guidelines for formulating more specific archeological studies within southeastern Utah.

The archeological record in this region is complex and extensive. Investigation of these four major topics, i.e., aboriginal land use, food storage strategies, paleonutrition-pathology-demography, and rock art will move us much closer to unraveling several archeological complexities in the study area. We would like to emphasize, however, that archeologists may make effective use of just such complex relationships to understand a broader range of past human behavior patterns. A much broader understanding of past aboriginal lifeways will only serve to enhance further our interpretive abilities in the national parks.

THE SOUTHEASTERN UTAH ENVIRONMENTAL CONTEXT

The deserts of North America have certain climatic features in common, including low precipitation of erratic frequency and quantity, high rates of evaporation, and high diurnal and seasonal temperature variability. The Great Basin, Mojave, Sonoran and Chihuahuan deserts are distinguished primarily by regional environmental differences of climate and terrain, as well as by their characteristic plant species (Thames and Evans 1981).

The Great Basin Desert is distinct when compared to the other deserts of North America, because the average temperatures there are lower than those of the deserts farther south. The frost-free period is relatively short, with killing frosts possible at any time during the year. It has been called a cold desert by Oosting (1956).

As part of the Great Basin Desert, southeastern Utah is in a particularly harsh environmental setting. It is one of two areas in Utah considered to be quite arid. The degree of aridity is determined by the interaction of precipitation with the factors, such as temperature, that control evaporation (Bailey 1981). The environment is greatly affected by temperature, precipitation and evapotranspiration. These climatic factors will be discussed later from both a regional and local perspective.

NATURE OF ARID LANDS AND DESERTS

Arid lands constitute approximately 8 percent of the earth's surface, or 28 percent of the total land surface (Whittaker 1975). Bailey (1981:13) states, "Aridity can be accounted for largely ... in climatic terms ...[T]errain subjected to the influence of aridity will lose all or nearly all water gained through precipitation to evaporation losses." This aridity, in turn, can be causally linked to high pressure systems; in the American Southwest these systems of descending air prevail almost all year (Bailey 1981:15). Bailey (1981:39) states, " In arid regions, lack of water undoubtedly represents the most effective extreme of all climatic conditions." Yet, desert regions result not only from limited rainfall but also from its temporal and spatial distribution. Noy-Meir (1973:31) states, "The master input to arid systems [precipitation] is not only discontinuous but also stochastic. The variation in timing and magnitude of precipitation events has a large random component." In arid lands, between-year variability in precipitation increases as the mean annual quantity of precipitation decreases. With respect to spatial distribution.

Noy-Meir (1973:33) states,

> Random spatial variation may be expressed by the lack of correlation in daily, monthly, or yearly rainfalls between two stations. The steepness at which this correlation decreases with distance depends on the size of rain systems and is an indicator of the spottiness of rainfall. It is greater for summer (thunderstorm) than for winter (cyclonic) rain, and it seems to increase from humid to semiarid and to arid regions.

In the Southwest, climate is conditioned by "...its distance from the equator, its variation in elevation above sea level, mountain barriers, semipermanent pressure centers, and the area's location with respect to the location of the hemisphere's air masses" (Davis 1978:3). Precipitation in this region is derived from extremely variable conditions that drive Gulf of California air masses (see Carleton 1991). Winter precipitation in the Southwest results from lagged movements of relatively warm Pacific or Gulf of California air masses into the region. Initial air masses cool and become stationary over the Colorado Plateau. Subsequent warm air masses superimpose themselves on these stable cold cells and produce winter precipitation (Thornthwaite et al. 1942). Less significant quantities of winter precipitation may also result from incursions of cold polar air. In summer, precipitation is produced along cold and/or warm fronts that invade the region from the Pacific of the Gulf of California. Marked diurnal variation between ground surface and air temperatures triggers intense, localized thunderstorms (Carleton 1991; Thornthwaite et al. 1942). Little

convective activity occurs during either spring or autumn; as a result, precipitation is limited during these seasons in the Southwest.

PRECIPITATION

Three types of weather systems are responsible for precipitation in Utah; they include frontal storms, thunderstorms, and closed lows. Systems formed over the eastern Pacific Ocean move in from the northwest to the southeast, from the west to the east, or from the southwest to the northeast portions of the state and are responsible for most winter precipitation (Greer et al. 1981). These frontal storms lose moisture as they pass over the Sierra or Cascade mountains. Therefore, the Utah Plateaus receive most of the available precipitation from these storms before they pass over southeastern Utah. The highest precipitation records are usually obtained on windward mountain slopes (Oosting 1956). As the descending air becomes drier and warmer, precipitation decreases on the leeward slopes, especially at lower elevations (Jeppson et al. 1968). This "rainshadow effect" (Thames and Evans 1981) is evident in southeastern Utah, based on winter precipitation data from several weather stations located on western or eastern sides of major landforms (see Table 2).

The station at Natural Bridges National Monument is situated on the western or windward side of the Abajo Mountains and receives a comparatively large amount of average annual precipitation for its elevation. On the other hand, the stations at Teasdale, Fruita, and Capitol Reef National Park registered smaller than expected (considering their elevations) mean annual precipitation amounts, probably due to their locations on the eastern or leeward side of Thousand Lake Mountain. The Widtsoe weather station was located in a trough between the Sevier Plateau and the Escalante Mountains, which helps to explain the relatively small amount of mean annual precipitation recorded there. The recorded average annual precipitation for the Bryce Canyon and Tropic stations was less than expected, given their elevations. This may be due to their locations on the leeward side of the Paunsaugunt Plateau. However, the partial record (where precipitation for certain months of certain years was not documented) for Bryce Canyon may contribute more to the relatively low amount of annual precipitation recorded for this station.

The higher, colder areas receive a greater amount of precipitation and more precipitation occurs as snow (Bailey 1981) (see Figures 6 and 7). According to Oosting (1956), ten inches (25.4 cm) of snow equals approximately one inch (2.54 cm) of water. From the data in Table 2, the ratio of precipitation (in millimeters of water) contributed by snow to the mean annual precipitation was greater for higher elevations than lower elevations. At elevations above 1,900 meters (6,232 feet), snow made up 25-50 percent of the total annual average precipitation. At elevations below 1,900 meters, rarely more than 30 percent, and usually less than 25 percent, of the mean yearly precipitation was contributed by snow. At higher elevations, an average of 25.4 cm (10 in) or more of snow can be found on the mountain slopes by mid-November, usually remaining there until mid-May. At this time, warm temperatures cause rapid melting, and the resulting water flows as surface run-off or percolates into the soil, adding to water reserves (Greer et al. 1981).

The primary source of summer (June to September) precipitation is from thunderstorms formed over the Gulf of California. An extensive area of thunderstorm activity occurs throughout southeastern Utah (Jeppson et al. 1968). These intense, active systems include damaging winds, hail, lightning, and heavy, erratic, shower activity (Greer et al. 1981).

Closed low-pressure centers aloft are often the cause of "quite general heavy precipitation" during October, late April, and May (Jeppson et al. 1968:4). The influence of topography is less with this type of storm, so the amount of precipitation does not necessarily increase with elevation (Greer et al. 1981). It is also more stable than thunderstorms in terms of the origin, path of movement, and season of annual occurrence (Oosting 1956).

The mean annual precipitation for southeastern Utah is 218 millimeters (8.5 inches), but there is considerable variability within this area. Generally, the maximum precipitation coincides with the hottest months, July and August, and averages 26 millimeters (one inch) per month. A secondary peak in lows aloft in October produces average precipitation equal to 26 millimeters (one inch). A minor winter frontal maximum averaging 18 millimeters (.70 inches) per month in December and January merges with a May "peak" (17

Table 2. Climatic data from stations in southeastern Utah and northern Arizona (Davis 1978; USDA 1936).

	Mean Monthly Precipitation (in mm)													
Station (Elevation)	J	F	M	A	M	J	J	A	S	O	N	D	MAP	LOR
Baker R.S. (2149 m)	43	38	29	48	26	31	49	51	28	56	36	45	480	9
Blanding (1951 m)	38	37	33	25	21	12	36	40	32	40	36	36	386	26
Bluff (1281 m)	14	18	17	14	12	9	22	14	18	20	10	16	184	20
Bright Angel R.S. (2561 m)	69	86	52	75	32	28	58	63	75	48	47	55	688	6
Bryce Canyon (2457 m)	10	38	31	36	21	14	39	56	37	40	19	18	359	13*
Capitol Reef (1677 m)	6	5	9	12	16	13	24	30	16	23	13	7	174	25
Canyonlands-ISKY (1799 m)	8	8	11	20	14	24	20	36	14	28	13	9	205	4
Canyonlands-NEEDLES (1537 m)	10	5	13	25	8	19	20	45	18	31	57	12	263	4
Escalante (1738 m)	25	23	25	15	14	12	41	52	34	26	14	20	301	28
Fruita (1677 m)	11	5	9	10	15	14	22	34	16	27	13	10	186	NA
Giles (1220 m)	10	8	10	14	13	6	13	18	19	14	15	5	145	12
Hanksville (1281 m)	10	8	9	7	9	11	15	21	17	16	8	9	140	21
Hite (915 m)	17	17	18	9	13	8	13	16	19	19	20	18	187	15
Kayenta (1768 m)	16	11	16	11	9	10	37	41	19	23	16	16	225	16
Lees Ferry (958 m)	9	15	11	15	7	4	20	25	15	16	11	11	159	15
Moab (1219 m)	21	18	23	18	20	9	23	19	27	24	17	24	242	42
Monticello (2134 m)	38	46	52	29	24	16	48	46	42	54	36	32	463	23
Natural Bridges (1982 m)	16	22	22	15	14	19	45	52	25	51	26	49	356	9
Pahrea (1220 m)	28	17	8	23	16	19	19	31	19	23	10	5	218	6
Teasdale (2134 m)	15	19	17	16	12	12	35	35	23	17	12	13	226	25
Tropic (2134 m)	27	24	22	18	15	10	38	43	33	21	17	25	293	38
Widtsoe (2210 m)	20	22	22	21	18	10	45	43	31	20	17	17	286	19

Station	MAS	LOR	MAT	MTCM	MTWM	LOR	FFD	LOR
Blanding	1033	20	10	-3	22	24	147	24
Bluff	264	11	13	-2	26	13	183	12
Bright Angel R.S.	3059	6	5	-7	16	6	69	6
Canyonlands-ISKY	403	4	11	NA	NA	4	164	4
Canyonlands-NEEDLES	190	4	11	NA	NA	4	NA	4
Escalante	592	15	9	-4	21	23	131	24
Fruita	567	12	12	NA	NA	15	138	-
Giles	262	11	11	-4	25	12	140	12
Hanksville	341	17	11	-6	25	19	146	19
Hite	NA	-	15	2	29	14	180	-
Kayenta	410	13	11	-3	24	14	164	16
Lees Ferry	118	14	16	2	30	9	229	14
Moab	414	41	12	4	20	41	166	41
Monticello	1669	16	7	-5	19	17	129	18
Natural Bridges	1421	9	10	NA	NA	9	NA	-
Teasdale	908	16	NA	NA	NA	-	121	14
Tropic	867	23	8	-2	20	22	102	21
Widtsoe	1023	12	6	-5	18	11	131	10

MAP=Mean annual precipitation in mm
LOR=Length of record in years
MAS=Mean annual snowfall in mm
MAT=Mean annual temperature in degrees C

MTCM=Mean temperature of the coldest month in degrees C
MTWM=Mean temperature of the warmest month in degrees C
FFD=Mean number of frost-free days

*partial record for some years

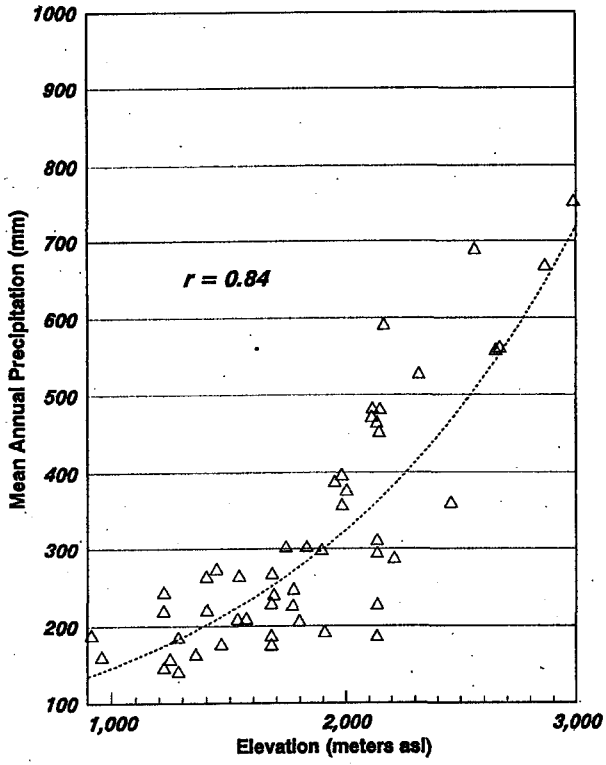


Figure 6. Elevation and mean annual precipitation, western Colorado and southeastern Utah.

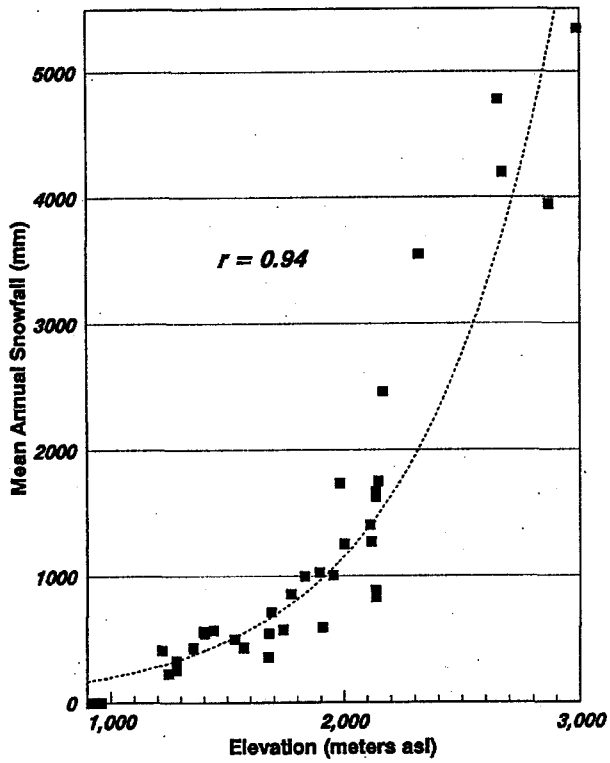


Figure 7. Mean annual snowfall and elevation, western Colorado and southeastern Utah.

millimeters or .65 inches) of lows aloft (Jeppson et al. 1968).

Climatic factors alone, however, do not provide us with a complete explanation for the distribution of arid lands in western North America. Bailey (1981) emphasizes the difficulty in defining geographic boundaries for arid regions in western North America, due to complex topography. He (1981:15) states, "The difficulty lies in the fact that aridity is controlled not by precipitation alone (which is fairly well known), but also by the factors that control evaporation (which are less well known)." Bailey (1981:15-17) points out that such arid areas can be delineated on the basis of a moisture index or the ratio of moisture gain (precipitation) to moisture loss (evaporation) (see Figure 8). This index is not based on absolute values of precipitation and evaporation.

Bailey (1981:18) states,

> Thus, a low-budget moisture regime with minimal evaporation may create a more mesic environment than one with more precipitation and higher evaporation. As evaporation is inhibited in cold climates, aridity tends to disappear as latitude and altitude increase ....

One should note that Canyonlands National Park is situated within a peninsula-like projection of the arid moisture province. This map of the moisture provinces reveals that the Island-in-the-Sky archeological project area is similar to the San Joaquin Valley, the Mojave Desert, and the Sonoran Desert with respect to the ratio between moisture gain and moisture loss.

Topography

Topography, then, can be seen to affect significantly the climate in southeastern Utah and the Colorado Plateau in general. The Rocky Mountains to the east generally block the movement of cold air from the northern and central plains. And, the Cascade and Sierra Nevada ranges to the west usually deflect incursions of air from the Pacific

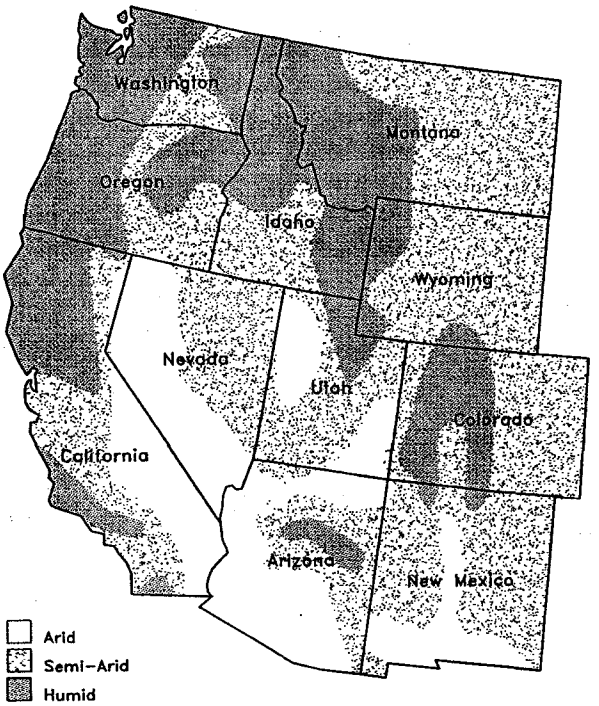


Figure 8. Moisture provinces in eleven western states, after Baily (1981).

Coast. A considerable amount of winter precipitation associated with the movement of Pacific air masses into Utah is deposited on the windward sides of the Wasatch Range. As a result, "... the Canyonlands country of southeastern Utah gets much less winter precipitation from frontal storms off the Pacific than the high plateaus immediately to the west" (Davis 1978:10). In summer, the invasion of warm, moist air from the Gulf of California is checked by the Uinta and the Wasatch ranges that bound southeastern Utah on the north and west, respectively.

The deserts of the Great Basin and the American Southwest, unlike many of the world's deserts, "... are located in higher latitudes and stand at higher altitudes than is typical of many other arid regions..." (Bailey 1981:13). Additionally, Bailey (1981:36-37) states,"The high desert areas of Nevada and Utah are also distinctive in vegetation; collectively they form the Great Basin Desert type. Thermally they are distinctly cooler in all seasons than the subtropical deserts." The Colorado Plateau places desert lands at higher elevations; this increase in altitude results in decreased heat extremes and increased cold extremes. We find that the average temperature lapse rate for Utah is approximately 3 degrees F for each 1,000-ft increase in elevation (Jeppson et al. 1968:49). They (1968:49) state,"Thus, higher elevations have a cooler temperature and a more limited potential to vaporize available water supplies than do areas at lower elevations." Despite the elevation of the Colorado Plateau we find that evapotranspiration exceeds precipitation. Jeppson et al. (1968:49) state,

> In other words, there is enough energy available to vaporize more water than normally occurs as precipitation. In general, only the mountainous areas above 7,000 feet receive precipitation in excess of amounts that could be used by the vegetation if all of the precipitation were to remain where it fell.

TEMPERATURE

The mean annual temperature for southeastern Utah is 10.8 degrees C (51.4 F). This can be an unsuitable criterion for characterizing climates. A more appropriate measure is the diurnal range of temperatures, that is, the difference between the daytime maximum and the nighttime minimum temperatures (Jeppson et al. 1968). Poor air drainage in the valleys, where cold air is often trapped, causes a larger diurnal temperature range than on the mountain slopes (Oosting 1956). In general, higher elevations exhibit lower temperatures than lower elevations (see Figure 9). And, as mentioned, the temperature lapse rate (change with altitude) varies with both time and location (Jeppson et al. 1968). In Utah, the average temperature reduction is approximately 3.5 degrees F per 305 meters (1,000 feet) of elevation (Greer et al. 1981).

A useful indicator of the severity of an area's climate is the number of days below 0 degrees C (32 degrees F) and above 32 degrees C (90 degrees F) that occur there. The more days that fall into either category, the fewer the organisms that will survive (Greer et al. 1981). According to Bailey (1981:37), "...the greatest seasonal ranges of temperature are developed in Utah."

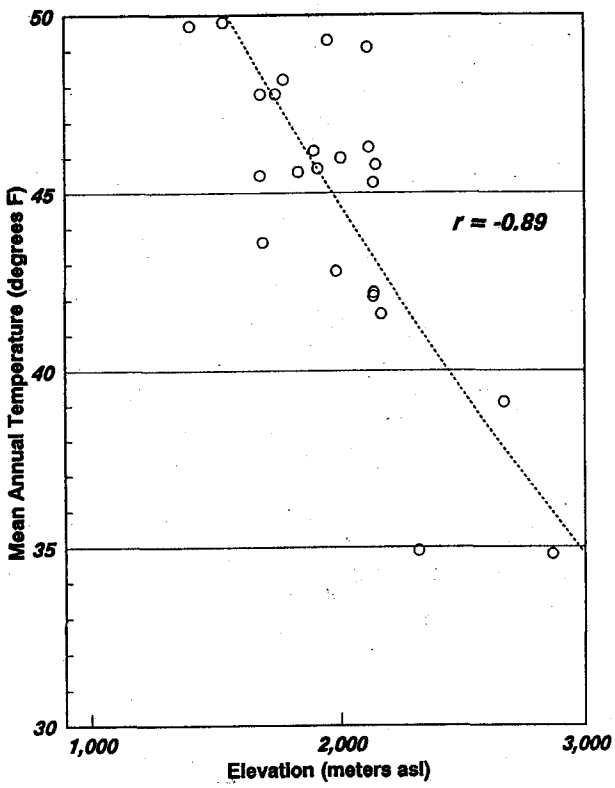


Figure 9. Mean annual temperature and elevation, western Colorado and southeastern Utah.

EVAPOTRANSPIRATION

Evapotranspiration is defined as the combined water loss from evaporation and transpiration (Jeppson et al. 1968). The potential evapotranspiration for an area is the amount of water loss that would occur if the plants and soil surface were never short of moisture (Thornthwaite 1954). If the soil surface is dry, evapotranspiration will drop abruptly when the vegetation freezes. Potential evapotranspiration is usually expressed as an index of the heat energy, in calories, available during the frost-free period to vaporize water and the corresponding amount of water vaporized (Jeppson et al. 1968).

Annual potential evapotranspiration for southeastern Utah is slightly less than 462 millimeters (18 inches) for high elevations (peaks in the Henry, Abajo, and La Sal mountains) and over 923 millimeters (36 inches) for low elevations (Glen Canyon Reservoir area). Compared to the average annual rainfall for the area it is obvious that, on the average, potential evapotranspiration exceeds precipitation (Jeppson et al. 1968).

Higher elevations (above 2,134 meters or 7,000 feet), with their lower temperatures, have fewer potential heat energy units to vaporize water and more precipitation than lower elevations. These factors allow a certain quantity of water to be available above the amount needed by plants. Conversely, since lower elevations receive less precipitation than higher elevations, actual evapotranspiration never reaches the potential amount, due to lack of water (Greer et al. 1981).

Since the amount of heat available to vaporize water is greatest during the summer months of June through August, the potential evapotranspiration rate is also highest at that time. For Blanding, that averages 139 millimeters (5.43 inches), compared to 29 millimeters (1.13 inches) of average precipitation (Jeppson et al. 1968).

EFFECTIVE TEMPERATURE AND LENGTH OF THE GROWING SEASON

Bailey (1960) calculated an index of effective temperature (ET) that informs us about the warmth and the duration of the growing season. Effective temperature ranges from 26 degrees C at the equator to 8 degrees C at either pole (Binford 1980; Kelley 1983). Binford (1980:13) states that effective temperature is " ... a measure of both the length and the intensity of solar energy available during the growing season." Effective temperature provides a more powerful measure of biotic production from a global perspective than mean length of the frost-free season. For the study area, effective temperature varies inversely with elevation on the Colorado Plateau (Figure 10).

The freeze-free period is defined as the number of days between the last day in the spring with a temperature of 0 degrees C (32 degrees F) or lower and the first day in the fall with a temperature of 0 degrees C (32 degrees F) or lower (Greer et al. 1981). This period does not correspond to the growing season for all plants since critical temperatures, at which damage to the plant can be expected to occur, may be higher than 0 degrees C (32 degrees F) for some plants. Therefore, a light (-1 to 0 degrees C or 30 to 32 degrees F) freeze in the spring may damage a substantial number of susceptible plants (Jeppson et al. 1968).

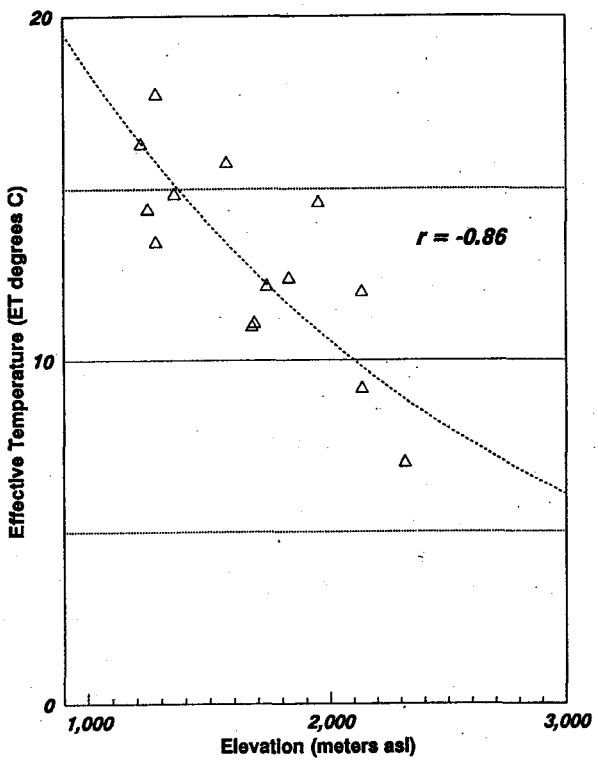


Figure 10. Effective temperature and elevation, western Colorado and southeastern Utah.

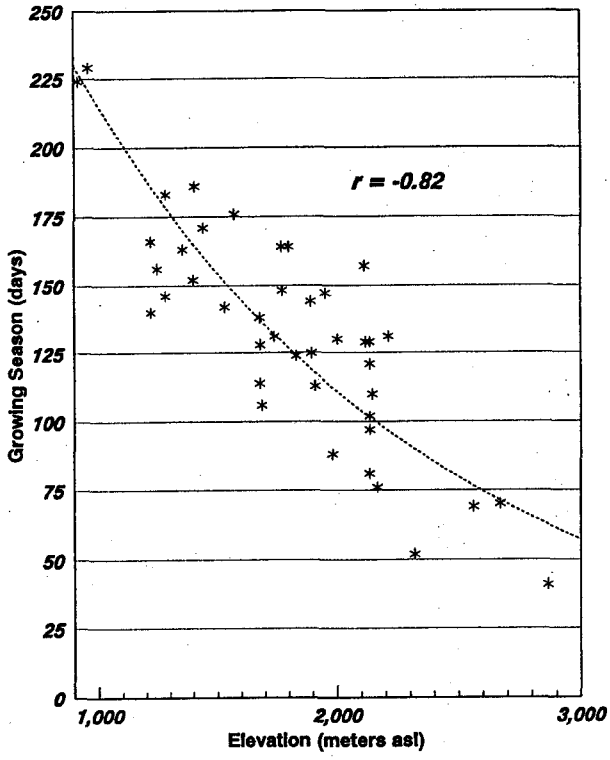


Figure 11. Growing season length and elevation, western Colorado and southeastern Utah.

Poor air drainage in the valleys makes the occurrence of a killing frost there more likely than in the foothill regions. This cold, trapped air accounts for the fact that the frost-free period is longer in the foothills than in the valleys, although the growing season generally becomes shorter with increasing elevation (Jeppson et al. 1968). The average freeze-free season in southeastern Utah ranges from less than 20 days in the mountains to more than 200 days at lower elevations and lasts from approximately May to September or October (Greer et al. 1981). The length of the frost-free period or growing season is inversely related to elevation (Figure 11). However, as mentioned, this relationship varies as a function of topography and patterns of cold air drainage. This microenvironmental variation may have had pronounced effects on aboriginal food production (Adams 1979).

The range of temperatures, amount of precipitation, and rate of evapotranspiration make southeastern Utah extremely arid. This aridity is tempered somewhat at higher elevations, with a general increase in precipitation and decrease in temperatures. The topography of the area has quite an effect on the climate and is responsible for the creation of microclimates at various elevations (Thames and Evans 1981). The greatest variability in the climate is present at the lower elevations. This is especially true in the valleys where poor air drainage tends to exacerbate the unpredictable nature of the climate.

PRIMARY PRODUCTION

Primary production in desert regions is quite limited, since precipitation inputs are low and evaporation from ground surfaces is very high. For example, areas within southeastern Utah receive a mean annual precipitation equal to 20 cm, yet mean annual evaporation (from lake surfaces) ranges between 100 and 120 cm. In general, the highest annual peak in precipitation for southeast Utah equals approximately 26 mm of rain; this moisture arrives during the warmest months of the year, i.e., July and August. At this time, there is very high potential heat energy, and this water is quickly evaporated. Evaporation almost always exceeds

precipitation during this portion of the summer. This discrepancy characterizes the desert west in areas situated below 2,000 meters above mean sea level (Bailey 1981:15). We see plant growth in such areas despite this apparent water deficit since plants capture moisture before it evaporates or is absorbed by porous, sub-surface soils. Furthermore, actual evaporation rates are conditioned by seasonal fluctuations in incident solar radiation; cloud cover; air temperature, velocity, and humidity; and aspects of ground surfaces. This evaporation figure approximates potential evapotranspiration (PET). Actual evapotranspiration (AET), or surface evaporation plus plant transpiration, exhibits a log-log relationship with net primary productivity (Rosenzweig 1968).

Terrestrial plants require tremendous quantities of water for photosynthesis, and much of this water is lost through transpiration.

Whittaker (1975:201) states,

> Land plants seem extravagant, in fact, in their use of water for transpiration. Many plants transpire 700 to 1000 g or more of water for every gram of net production Some plants of dry environments have special photosynthetic adaptations (C_4 and crassulacean acid metabolism) and make do with less water loss—50 to 300 g per g of net production—but even these seem 'efficient' in water use only by comparison with other land plants. The availability of water for such loss is a major determinant of productivity on land. In arid climates there is a nearly linear increase in net primary productivity with increase in annual precipitation.

Although we find that arid lands are controlled primarily by precipitation inputs, temperature becomes a relevant factor particularly in portions of the Great Basin and the Colorado Plateau. As mentioned, these areas are cool deserts. Noy-Meir (1973:34) states,

> Where rain or snowfall in a cold season (high latitude or altitude winter-rainfall deserts, e.g. parts of Central Asia, Great Basin), root and shoot growth are almost completely inhibited by low temperatures until spring, even though moisture is available. Since evaporation losses are also low in winter one may assume as a first approximation that the cold season precipitation is stored until the growing season starts. However, the eventual utilization and production from this water may sometimes be reduced by after-effects of an extremely cold winter.

Net above-ground primary productivity or plant production in desert ecosystems averages between 10 and 250 dry grams/sq m/year; it is varies between 100 and 600 dry grams/sq m/yr for semiarid lands (Noy-Meir 1973:44; Whittaker 1975:224, Table 5.2). Primary productivity for arid ecosystems is quite low. Plant biomass, or standing crop, for arid and semidesert ecosystems is low (0.7 kg/sq m) compared to that for the temperate deciduous forest (30 kg/sq m) and the woodland/shrubland (6 kg/sq m). Secondary production for the desert and semidesert ecosystems equals 0.389 g/sq m/yr (see Whittaker 1975:226, Table 5.3).

VEGETATION

The close relationship among plants, soil, and climate insures that vegetative cover is a useful index of aridity (Thames and Evans 1981). An arid environment requires that organisms possess considerable flexibility. General adaptations of desert plants include the presence of distinct leaf, stem, and root structures, specialized photosynthetic pathways, heat and salt tolerance, resistance to cell sap desiccation, and well-timed leaf abscission (Pianka 1983). Plants inhabiting a cold desert must survive despite the lack of water, the wide range of daily temperatures, and the brevity of the frost-free period.

In the Great Basin or Intermountain Region, vegetation has been divided into zones (Cronquist et al. 1972). According to Billings (1951:103), a vegetation zone is "...a large climax unit whose boundaries are caused primarily by the effects of climate and soil on the distribution of the dominant species of the zone." Lowland or intermontane valley zones are widespread and interconnected, unlike montane zones which are distributed like "altitudinal belts" around mountain slopes (Cronquist et al. 1972).

There are nearly as many versions of vegetation zones as there are authors who have compiled them. This may be due, in part, to the intermingling of the vegetation in the various zones, the variability among zones in different areas, and the arbitrary manner in which some zones have been delineated. The following review gives a brief zonal classification for the Canyon Lands Section of the Colorado Plateau Division, after Cronquist et al. (1972). A complete overview of the different interpretations of vegetation zones in the Great Basin is presented by Graham (1937).

The Canyon Lands Section averages between 1,524-1,829 meters (5,000-6,000 feet) in elevation with four isolated laccolithic mountain areas: the La Sal, Abajo, Henry, and Navajo mountains. The lowest elevation in this region is Lake Powell at approximately 1,113 meters (3,650 feet) above sea level. The highest elevation is Mount Peale, in the La Sal Mountains, which rises to 3,878 meters (12,721 feet) above sea level. The remaining canyon areas, except for the eroded valleys of the Colorado and San Juan rivers, lie above 1,524 meters (5,000 feet) (Cronquist et al. 1972).

INTERMONTANE VALLEY ZONES

The Intermontane Valley Zones replace each other generally from south to north and from lower to higher elevations. They include the Creosote Bush, Shadscale, Sagebrush, and Pinyon-Juniper Zones. The Creosote Bush (*Larrea tridentata*) Zone is replaced at approximately the 37th parallel by the Shadscale Zone (Cronquist et al. 1972). Therefore, it does not occur in southeastern Utah.

The Blackbrush Community is transitional between the Creosote Bush Zone and the Shadscale Zone. The dominant species is blackbrush (*Coleogyne ramosissima*). It occurs throughout the lower elevations, up to 1,524 meters (5,000 feet) in some places. It appears as dense to open stands of evergreen shrubs and is often interspersed with galleta grass (*Hilaria jamesii*) (Cronquist et al. 1972).

The Shadscale Zone occurs in the valley bottoms, extending northward. The dominant species is shadscale (*Atriplex confertifolia*). At the upper limits (above 1,524 meters) of this zone, is a shadscale-galleta grass association which grows on relatively non-alkaline, sandy soils (Cronquist et al. 1972).

The Sagebrush Zone is at a higher elevation and receives more annual precipitation (over 180 millimeters) than the Shadscale Zone. In the southern part of the region, the sagebrush community occupies a narrow altitudinal belt on the rocky sides of the mountains, usually above 1,524 meters (5,000 feet). The dominant species is big sagebrush (*Artemisia tridentata*). The galleta—three awn grass community (*Hilaria jamesii-Aristida longiseta*) occupies large areas within this zone in southeastern Utah. It is usually found above 1,524 meters (5,000 feet) in sandy soils (Cronquist et al. 1972).

The Pinyon-Juniper Zone is associated with the mountains and is often considered a montane zone (Billings 1951). In southeastern Utah, it occurs often enough in the higher valleys to be included in the Intermontane Zones. It is usually found between 1,524-2,439 meters (5,000-8,000 feet), with insufficient moisture (annual averages of less than 308 millimeters) determining its lower limits. The one-seed juniper (*Juniperus monosperma*) dominates the drier sites at lower elevations. As elevation increases, the one-seed juniper is replaced by the Utah juniper (*Juniperus osteosperma*) and the two-needle pinyon (*Pinus edulis*). Big sagebrush is the most common understory shrub (Cronquist et al. 1972).

MONTANE ZONES

The Montane Zones differ from the Intermontane Valley Zones in that they occur as distinct belts on mountains, due to the influence of precipitation, temperature, soil, and topography on the composition of species. These zones dip toward the south, due to increased solar radiation on these exposed slopes. Cronquist et al. (1972) have expanded the Wasatch Series of Montane Zones (Billings 1951) to include the Utah Plateaus and the Canyon Lands. These include the Chaparral and Ponderosa Pine Zone, the Douglas Fir-White Fir-Blue Spruce Zone, the Engelmann Spruce-Subalpine Fir Zone, and the Alpine Tundra Zone.

The Chaparral and Ponderosa Pine Zone is present at 1,829-2,744 meters (6,000-9,000 feet) in the southern latitudes. The dominant chaparral community species are Gambel oak (*Quercus gambelii*) and bigtooth maple (*Acer grandidentatum*). In the mountains, the Gambel oak forms interrupted communities on the

drier, lower slopes between 1,829-2,439 meters (6,000-8,000 feet), alternating with pinyon-juniper woodland and ponderosa pine forest in the draws. The ponderosa pine (*Pinus ponderosa*) community forms the upper limits of the zone (Cronquist et al. 1972). On the cool northern slopes, stands of ponderosa pine tend to be thicker and intermingle with Douglas fir. At the higher elevations, aspen (*Populus tremuloides*) is often associated with ponderosa pine (Elmore 1976).

The Douglas Fir-White Fir-Blue Spruce Zone occurs between 2,439-3,049 meters (8,000-10,000 feet) above sea level. The Douglas fir, (*Pseudotsuga menziesii* var. *glauca*) is the dominant species throughout all the mountains in the Wasatch Series. The white fir (*Abies concolor*) is the second dominant species in the mountains and plateaus of the south and southeast. The blue spruce (*Picea pungens*) and white fir require more moisture than the Douglas fir, ponderosa pine, and limber pine (*Pinus flexilis*), which are found in the drier areas of the zone. Ponderosa pine occurs at lower elevations, the limber pine occurs primarily at upper elevations, and the Douglas fir is found throughout the zone. Aspen occurs in this zone, either alone or in association with smaller trees and shrubs (Cronquist et al. 1972).

The Engelmann Spruce-Subalpine Fir Zone is found between 2,896 meters (9,500 feet) and the timberline, approximately 3,201-3,354 meters (10,500-11,000 feet) above sea level. The dominant species shifts from the subalpine fir (*Abies lasiocarpa*) at the lower elevations to Engelmann spruce (*Picea engelmannii*) at the upper elevations within this zone. Limber pine is restricted to the dry, steep, and rocky southern exposures. Aspen also occurs in association with subalpine fir. The forested areas are often interrupted by subalpine meadows that consist of shrubs, grasses and sedges (Cronquist et al. 1972).

The Wasatch Alpine Tundra Zone occurs as isolated "islands" on the very highest mountain peaks. In southeastern Utah, this zone occurs only on the high peaks of the La Sal Mountains, which rise to almost 3,963 meters (13,000 feet). The short growing season, freezing nighttime temperatures, and shallow, poorly decomposed soils in the tundra zone limit vegetation to patches of grasses and sedges (Cronquist et al. 1972).

The tangible evidence for the effect of altitude on climate is present in the vegetation zones of southeastern Utah. As elevation increases, vegetation becomes more luxuriant and dominant species become larger, due to the increased precipitation and decreased temperature and evapotranspiration. This general trend holds for all the zones except the Alpine Tundra Zone, where the climate becomes as severe as the lower desert valley zones. In this instance, nighttime temperatures rather than low precipitation, limit vegetative growth.

FAUNA

Animals are dependent on certain plants for food or cover. Therefore, plant species that dominate vegetative zones have associated fauna. The mountains in southeastern Utah may be viewed as islands in the desert, differing from the hot, lower elevations in climate as well as fauna and flora (Olin 1961). Consequently, larger mammals are found at higher elevations where water and vegetation are adequate to support them. The most abundant large mammals in historic times have been the desert bighorn sheep, mule deer, elk and pronghorn antelope.

Desert bighorn (*Ovis canadensis* ssp.) inhabit the La Sal, Abajo, and Henry mountains near or above the timberline (approximately 3,354 meters above sea level), as well as the canyons, cliffs, and mesas of the canyonlands of southeastern Utah (Hansen 1980). During winter, the sheep living at higher elevations often seek the shelter of forests at lower elevations. Occasionally, they cross valleys or other mountain peaks to find food (Rue 1967). Bighorn sheep are grazing animals. When grass is covered by snow, however, they become browsers, feeding on the understory of the coniferous forest and the shrubs of the alpine tundra (Calahane 1961). This pattern is the same at lower elevations, where the browse consists of shrubs, primarily blackbrush (Hansen 1980).

The desert bighorn of southeastern Utah (*Ovis canadensis nelsoni*) is generally lighter in weight, color, and pelage than the Rocky Mountain variety (*Ovis canadensis canadensis*). However, the two are classified as separate subspecies for ecological rather than morphological reasons. The desert bighorn is defined as any bighorn living under relatively arid desert conditions (Manville 1980).

Mule deer (*Odocoileus hemionus*) occupy several habitats, ranging from the desert valley zones to the lower edge of the coniferous forest zones. They are typical of the western mountains (Olin 1961). In general, these these animals migrate to higher elevations in the spring and spend summer in the mountains at approximately 2,287-2,439 meters (7,500-8,000 feet) among the aspens and pines (Cahalane 1961). As winter approaches, they migrate down to the valleys. Mule deer are browsers, feeding primarily on the leaves and twigs of shrubs and deciduous trees and, when available, on grasses and herbaceous plants (Burt 1964).

Elk or wapiti (*Cervus canadensis*) have been reintroduced into southeastern Utah from herds in Yellowstone National Park. The indigenous herds were decimated, along with the bison, in the 1800's, as white settlers came into the area. These animals inhabit wooded areas and high mountain meadows (Rue 1967). During the summer months, the herds are small and widely scattered near 2,439 meters (8,000 feet) or higher in the ponderosa pine forest. In the fall, they migrate in large herds down to sheltered, grassy valleys to spend the winter (Olin 1961). Elk feed on grasses, herbaceous plants, twigs, and bark. Unlike other deer, they paw aside the snow to find grasses and fescues (Rue 1967).

Pronghorn antelope (*Antilocapra americana*) inhabit the grasslands, mesas, and sagebrush plains of desert valley zones. Formerly, they were found in the lower elevations, but now are more common to the pinyon-juniper woodland, approximately 1,829 meters (6,000 feet) in elevation. Pronghorn are migratory, moving in large herds from mesa ranges to valleys in a seasonal cycle (Olin 1961). Primarily grazing animals, competition from cattle has made some browsing necessary for the antelope, particularly in winter. Foods consist of shrubs and grasses (Cahalane 1961).

Larger animals are able to inhabit the arid region of southeastern Utah, due to high elevation areas with above-average precipitation. These moisture islands provide food and water on a seasonal basis, allowing the animals to live in a climate that is less than hospitable to living organisms. Ungulate ecology and physiology is discussed in greater detail within the broader framework of aboriginal land use strategies.

ENVIRONMENTAL CONTEXT

ISLAND-IN-THE-SKY ENVIRONMENT

The study area is characterized as having a cold, middle-latitude, semi-arid climate. Climatic features of this environment center around precipitation and evapotranspiration patterns. Potential evapotranspiration indices for the Island-in-the-Sky range from about 61 cm to 69 cm (24 to 27 inches); however, average precipitation on the Island is generally only about 21 cm (8.27 inches). This large difference between precipitation and potential evapotranspiration makes effective moisture a critical environmental factor. Precipitation varies greatly, both annually and spatially. For example, the Island mesa receives slightly more moisture than the White Rim. Table 3 shows variation in recent precipitation and temperature patterns on the Island mesa. This data was derived from daily records kept by park staff on the Island and logged on monthly National Oceanic and Atmospheric Administration forms (WS Form E-15).

The highly permeable and porous sandstone of the study area is an excellent aquifer. Although not as numerous as in other areas of the park, the Island mesa does have springs and seeps at the contacts between sandstones that permit water percolation downward to finer-grained rock, allowing water to concentrate. Holman Spring, where prehistoric storage structures and rock are situated, is at the contact between Wingate Sandstone and the Chinle Formation. Seeps also are numerous at the contact of the White Rim Member and the underlying Cutler Formation.

Much of the soil in the study area is shallow, dry, and without distinct horizons. Many areas have less than 20 inches (50.8 cm) to bedrock, although some portions of the Island mesa are deeper. Aeolian deposits cover Gray's Pasture, Willow Flat, and several smaller areas on the White Rim. Figure 12 shows the range of soil classifications that describe the Island mesa.

Spatial heterogeniety of precipitation and edaphic factors are the primary causes of vegetation patchiness in this environment. Plants may vary dramatically because of substrate variation. The current

vegetation of the study area consists of plants that either survived the climatic changes of the Pleistocene or remained close enough to recolonize their present zone. Almost all plant species have undergone evolution and/or range size fluctuations during Pleistocene and recent times. These species are subjected to high water stress during most of the growing seasons, and winter temperature are cold enough to exclude many drought-adapted species that thrive further south in the Sonoran and Chihuahan deserts (Loope 1977).

The Island mesa can be divided into two broad vegetation categories: shrub-grassland and pinyon-juniper. Figures 13 and 14 detail the variation of vegetation communities in the study area. In general, grasslands occur on deep aeolian sand (Figure 15). Blackbrush (*Coleogyne ramosissma*) dominates shallow (less than 18 inches) regolith. Pinyon-juniper vegetation dominates areas where regolith is restricted chiefly to rock fissures (Figure 16). Additional discussions of the vegetation of Canyonlands are found within the section of this report concerning ecofactual remains.

Table 3. Mean monthly meteorological data for the Island-in-the-Sky District (March 1984 to May 1990).

Month	Precipitation (inches)	Temperature (F) Low	High
January	.47	17.62	35.50
February	.41	23.45	41.83
March	.70	32.43	52.23
April	.99	40.61	63.31
May	.43	48.73	73.34
June	.46	61.31	85.61
July	1.72	63.82	88.58
August	.80	62.67	86.90
September	1.07	52.33	75.73
October	1.38	42.57	63.95
November	.75	30.10	48.67
December	.45	21.25	38.57

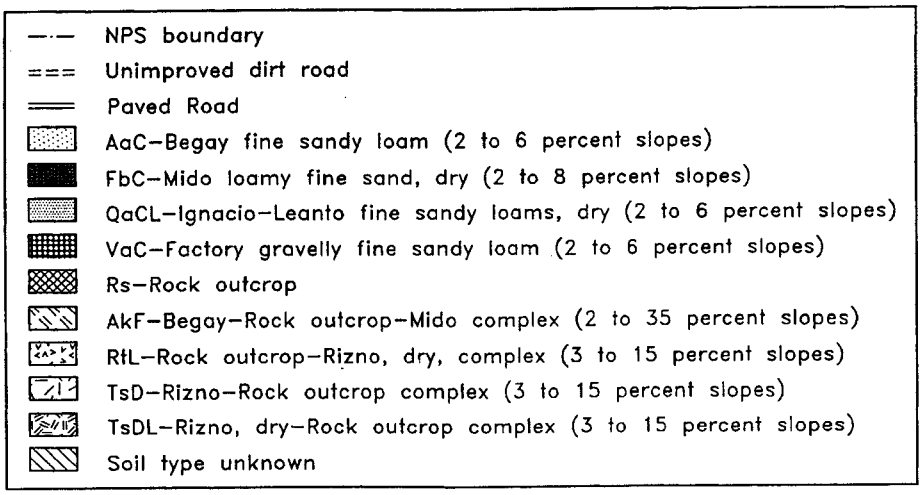
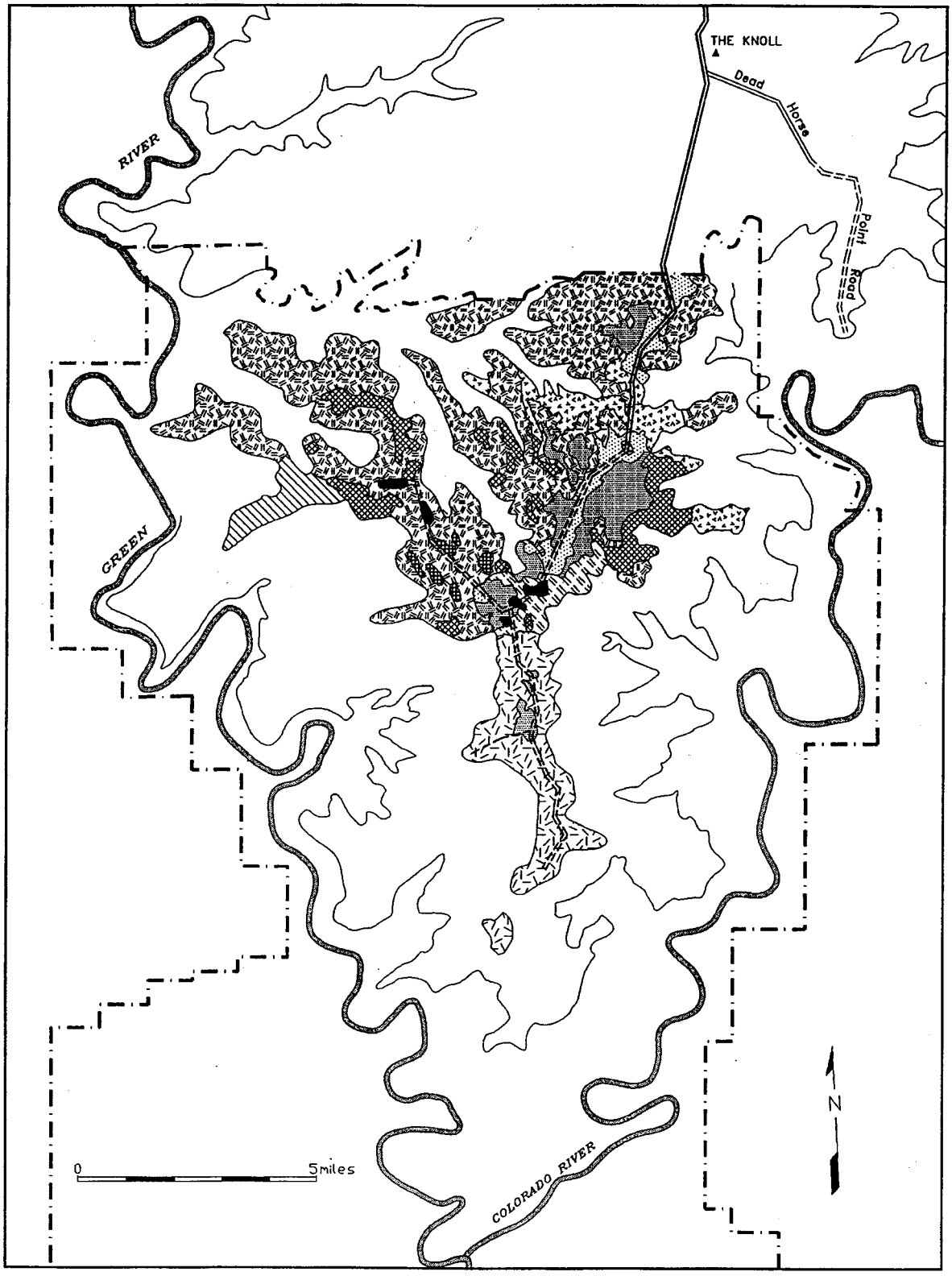


Figure 12. Map of soil and rock outcrop types within the Island-in-the-Sky District. Legend above, map on facing page.


THE KNOLL
Dead Horse Point Road
GREEN RIVER
COLORADO RIVER
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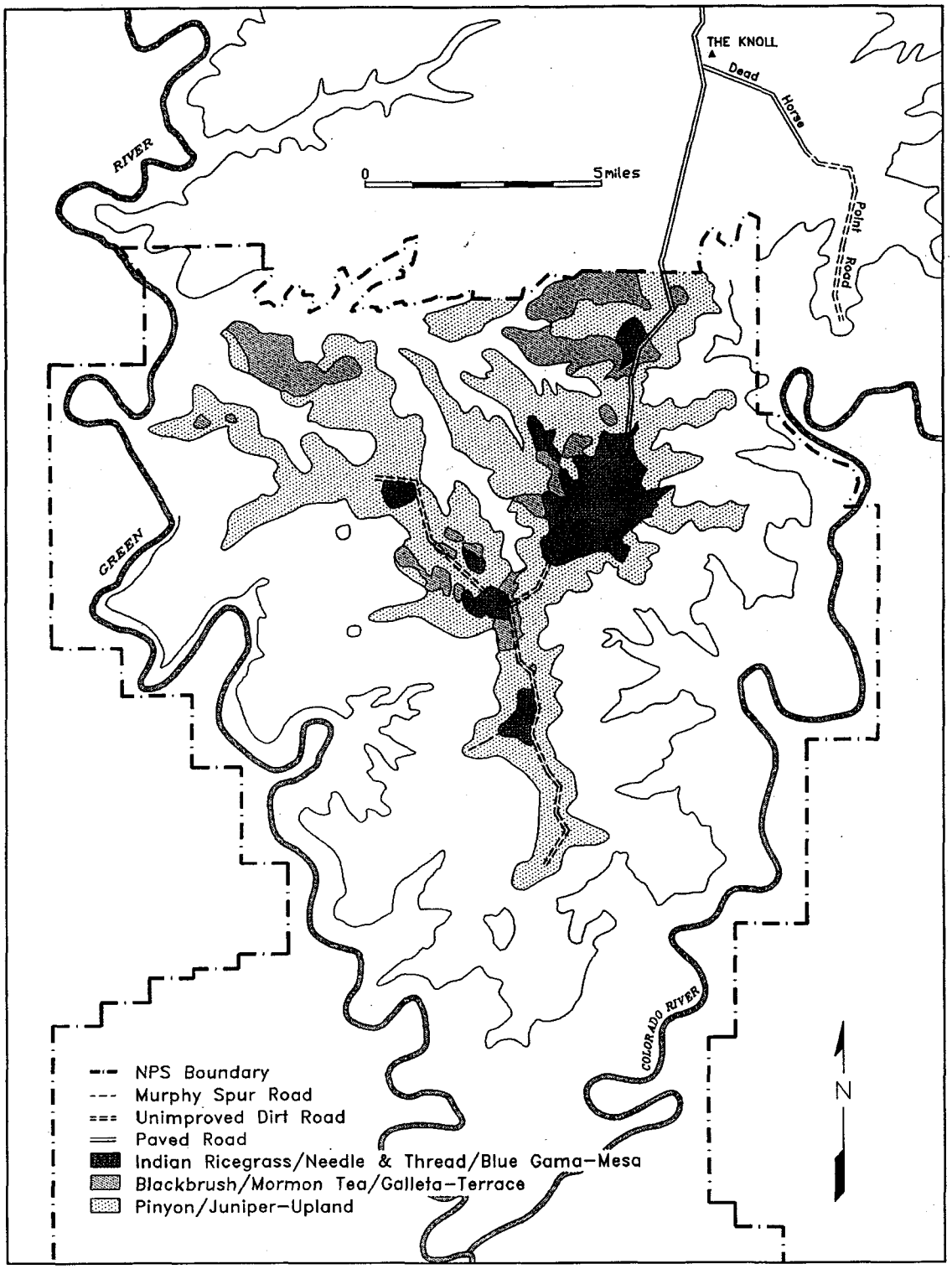


Figure 13. Contemporary vegetation zones within the Island-in-the-Sky District.

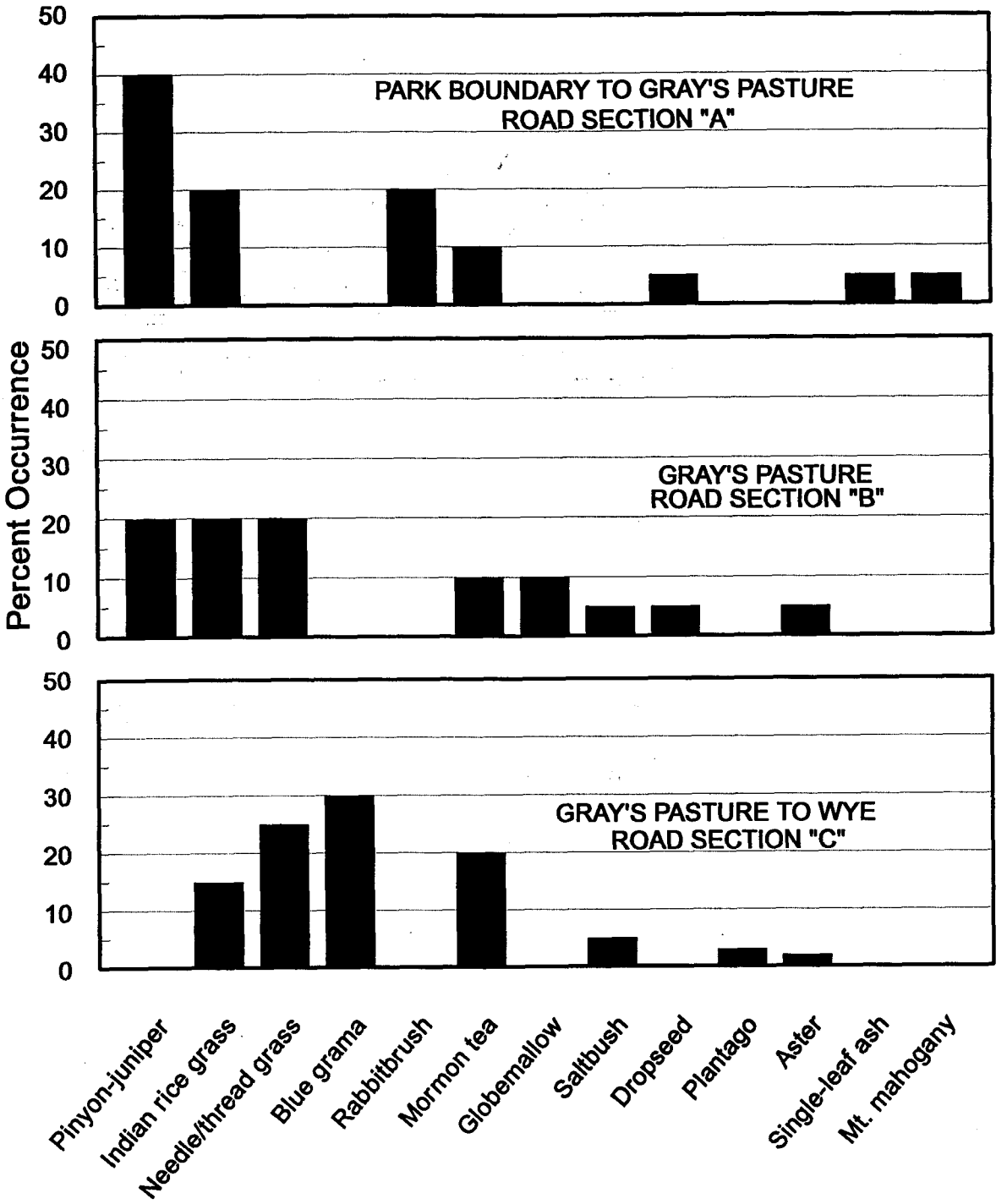


Figure 14. Results of a vegetation transect study, Island-in-the-Sky District.

Figure 15. Grassland community in Gray's Pasture, view to the north.

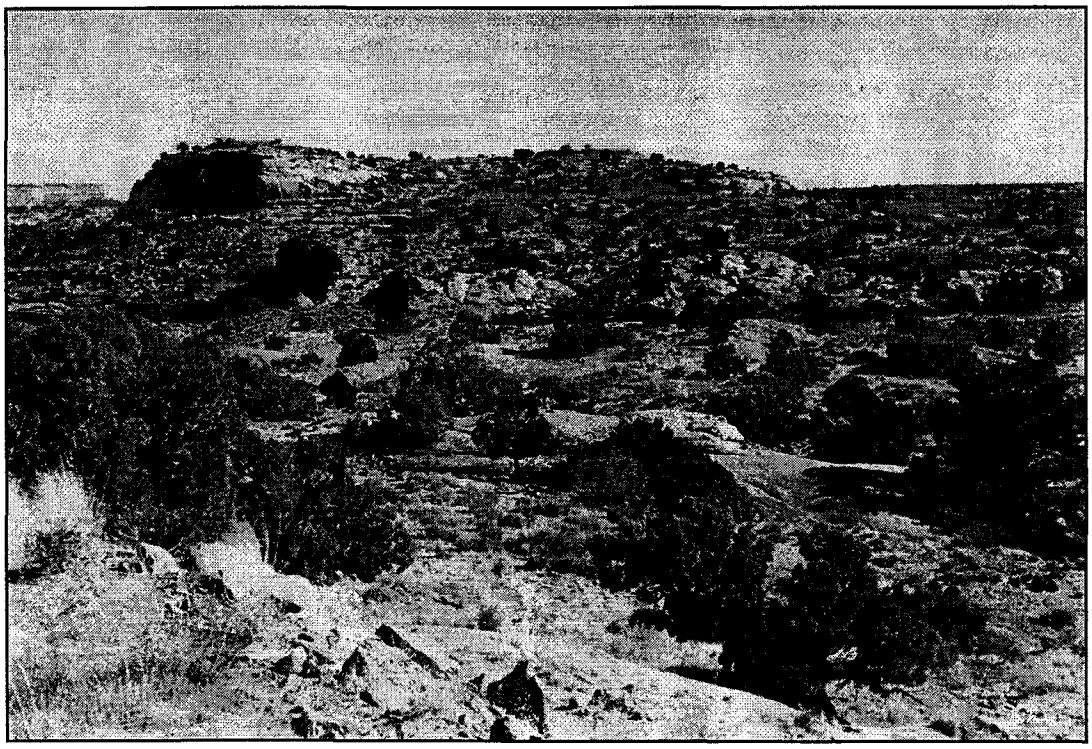


Figure 16. Pinyon-juniper community surrounding the Alcove Spring location (42SA8512), viewed from Station 151W.

ABORIGINAL LAND USE IN SOUTHEASTERN UTAH

INTRODUCTION

Aboriginal land use is one of the four research domains that were originally identified for investigation in the Island-in-the-Sky project. Prehistoric land use strategies was selected for several reasons. First, recent hunter-gatherer research in anthropology has focused on the variable ways that foragers and collectors distribute themselves across the landscape in relation to critical resources and other human groups (e.g., Binford 1980, 1982, 1983a, 1983b; Kelly 1983; Moore 1981; Schalk 1978). Second, archeologists have begun to develop appropriate methods for mapping the distribution of all archeological remains across vast areas of the landscape. Originally, these archeological efforts were described as studies in "non-site" or "off-site" archeology (e.g., Dunnell and Dancey 1983; Foley 1980, 1981a, 1981b, 1981c; Thomas 1975). These studies have become quite sophisticated and are currently performed within the framework of distributional archeology (e.g., Ebert 1986; Ebert and Kohler 1988; Ebert et al. 1983; Sebastian and Larralde 1989; Wandsnider 1989). Third, both hunter-gatherer studies and distributional archeology provided a framework for investigating artifact scatters. Such scatters of lithic debris and relatively few tools had generally not been systematically investigated in the American Southwest.

Archeological remains are quite diverse and they appear to be ubiquitous. Limited archeological survey in the Island-in-the-Sky District of Canyonlands National Park revealed many artifact scatters, quarry locations, isolated masonry "granaries," rock shelters, and rock art panels. The Island-in-the-Sky road project was confined to a narrow transect that was 100 meters wide and approximately 45 kilometers long. From the viewpoint of the archeologists, the project area was quite large; however, it represents about 0.04 percent (4.5 sq km/10,314 sq km) of the average range of a Southern Paiute band. Given this fact, we were compelled to develop a very general model of aboriginal land use that would enable us to place the archeological record of the project area into a broader behavioral perspective. This land use model consists of two components: (1) an expanded, extensive land use strategy based on highly mobile residential groups involved in plant exploitation and caching during the growing season; and (2) a collapsed, intensive pattern of land use based on logistically mobile groups involved in ungulate hunting and consumption of stored plants.

DETERMINANTS OF LIVING SPACE

The areal extent of land required for viable subsistence needs in the study area can be couched within the concept of "range," as used in investigations of spatial behavior in the biological and ecological sciences (Burt 1943; Jewell 1966). The concept of "home range" is useful initially in organizing the relationships between the mobile activities of human groups and exploitable resources. The term "home range" will refer in this case to the area habitually exploited by the group. Home range is differentiated from "territory" by the fact that the home range is not defended and is not used exclusively by an individual or small group. Overlapping home ranges are often the case for most species (see Mitani and Rodman 1979). A related concept, stemming from animal ecology, that is useful here is that of "total range" or "life time range"; i.e., that area utilized by those individuals of a group throughout their lifetime, including seasonal home ranges and migration routes. These concepts have been used in anthropological archeology to emphasize the spatial scale at which an understanding of "sites," as focused on in discussions of subsistence-settlement behavior, should be approached (e.g. Binford 1982; Ebert and Kohler 1988; Foley 1981a; Kelly 1983; D.H. Thomas 1981).

In general, the size of the home range for all mammals is determined by the relative density of food items, their pattern of dispersion, and their energy content. Home range size tends to vary inversely with density of food resources. In arid and semi-arid environments, home range size for human groups has been shown to have an inverse relationship with precipitation (see Birdsell 1953; Schalk 1981; Vorkapich 1981). Home range size is also considered to be determined by the degree of resource clumping, that is, the more spatially or temporally clumped the necessary resources in a given environment, the larger the area required to ensure an adequate supply of these resources (Schalk

1981:59-60; Weins 1976:97-98). In environments where precipitation is low and resources are highly clumped, extensive home ranges and residential mobility among aboriginal populations practicing little or no horticulture is to be expected. Cross-cultural data reported by Kelly (1983:296297) show that hunter-gatherers with a greater dependence on fauna will utilize a greater land surface through logistical mobility than those most dependent on plant foods. These latter groups, however, exploit a greater percentage of land residentially than those dependent on animals.

Spatial variation in rainfall, runoff distribution, and edaphic diversity are attributed to the observed resource patchiness in arid environments. The resulting resource structure affects both species diversity and the adaptive behavior of organisms in the environment. This adaptation is observed in highly mobile organisms compensating for temporal variability and low spatial correlations in precipitation (Noy-Meir 1973, 1974).

In general, annual precipitation offers a rough estimate of net above-ground productivity in arid environments (Whittaker 1975:65, Fig.3.8). However, these environments are usually characterized by great spatial variation in rainfall. This spatial heterogeneity in precipitation is one of the primary causes of patchiness in the environment of southeastern Utah.

EXTENSIVE LAND USE STRATEGY

An extensive land use strategy might be expected during the growing season, due to the increased availability of primary biomass. Temperatures increase markedly during this season and summer rains increase in frequency. Precipitation, however, exhibits a very patchy distribution. Aboriginal groups would be expected to increase residential mobility in order to monitor resource availability and to track the geographical distribution of precipitation and resulting primary production. As a consequence, we find that "...groups primarily dependent on plant foods cover a greater area of land [and cover it more intensively] via residential mobility than do fauna-dependent groups" (Kelly 1983:296). Residential groups of producers and consumers practiced an "island hopping" strategy during the growing season, as they moved between patches of plant resources. Wild plant resources were harvested and put into storage in small masonry food caches throughout the summer home range. In order to gain insights into the size of this extensive summer range, we will examine some extant anthropological literature dealing with the interrelationship between land use area and precipitation in arid environments. Cross-cultural analyses will be used here in order to develop some general expectations for the arid lands in southeastern Utah.

One of the key factors in the examination of aboriginal land use patterns is the interrelationship between human population and appropriate food resources. Birdsell (1953) provided one of the most provocative studies of the relationship between hunter-gatherer population size, tribal area, and food availability for 123 interior aboriginal tribes in Australia. Birdsell (1953) argued that since plant and animal biomass is directly controlled by locally earned water in desert environments, rainfall could serve as a proxy for food resource abundance. He (1953:205-206) then found that more than 64 percent of the variation in tribal area size could be explained by variation in mean annual precipitation. Since Australian tribal size remained relatively constant, both tribal area and population density varied as an inverse logarithmic function of mean annual precipitation.

Since Birdsell's (1953) classic anthropological study, other investigators have either attempted to evaluate his results or to develop independent approaches to the study of the ecological determinants of human population size and density (e.g., Baumhoff 1958, 1963; Casteel 1972, 1979, 1980; Martin and Read 1981; Vorkapich 1981; Yengoyan 1968). In fact, Birdsell (1978) reexamined this basic ecological relationship using an expanded data base containing 164 tribes and 65 environmental variables (most related to precipitation). Birdsell (1978:35) found that median annual rainfall "... really expresses ecological relationships better than mean annual rainfall, whose central tendencies are apt to be distorted by extreme values." The explained variance in tribal area size and precipitation increased from 64 percent to 72 percent.

Vorkapich (1981) examined the interrelationship between aboriginal population density and mean annual precipitation for 25 groups in the Great Basin. Equestrian groups were omitted from this study (Vorkapich 1981:218). The interrelationship between these two variables was logarithmic and exhibited a correlation coefficient equal to 0.44. Although

Vorkapich (1981:223) suggests that this lower correlation can, in part, be attributed to small sample size and a very limited range of precipitation, she offers a set of interesting qualifications. Vorkapich points out that the Great Basin, as opposed to Australia, is characterized by much greater topographic variation, a number of predictable springs, and greater resource productivity,

> The most important and obvious difference between the two regions is the topography of the Great Basin. In general, the desert valleys ranging about 15 miles in width and 50 in length, are flanked on the east and west by high mountains, so that the range in elevation over a short distance may extend over 8,000 feet. The mountains have the effect of capturing precipitation, often in the form of snow, and releasing it in streams and springs at the base (Vorkapich 1981:225).

Discussions of home range—the life space used by an organism on a daily basis—generally assume that critical resources are homogeneously distributed. Ecologists are quite aware that such essential resources are patchily distributed, both spatially and temporally (see MacArthur and Pianka 1966; Wiens 1974). And, some investigators have examined the effect of resource patches on the size, shape, and use of home ranges (see Don and Reynolls 1983). Yet, the effects of clumped resource distributions have not been intensively studied by anthropologists and archeologists.

Lee (1976) emphasized that the spatial and temporal distribution of critical resources may be reflected in fluctuations in home range and/or annual range size, given a long-term perspective. He (1976:95) argues that the flexible size and composition of San local groups, as well as their flexible use of water sources, mirrors the need for periodic expansion of annual home ranges. These shifts in annual home range size occur in response to the long-term drought cycles in the Kalahari region. Although Lee does not provide empirical data, he suggests that San maintained access to much larger annual home ranges than they in fact usually used. San local groups did not cover this entire range throughout the course of a year but social ties between groups were maintained in order to insure periodic use of restricted parts of a vast area.

Range Size

Ethnographic and ethnohistoric information about aboriginal land use in southeastern Utah is limited, at best. Data regarding areas used by groups in the Great Basin and western portions of the northern Colorado Plateau during the nineteenth century is, however, available. Although differences in the physical environment of localities in the Great Basin and northern Colorado Plateau exist, similarities that permit some analogy at a regional scale are apparent as discussed above. Both Paiute and Ute groups are considered to have used the study area as logistically organized collectors after 1300 A.D. and until the inception of Euro-american settlement (Bettinger and Baumhoff 1982; Euler 1966; Fowler and Fowler 1981; Kelly 1964; Schroeder 1965; Stewart 1966; Weber 1979). Information about aboriginal groups using the Great Basin and western portions of the northern Colorado Plateau during the nineteenth century is used here to give us some understanding of the conditions and the extent to which an area like the Island-in-the-Sky was utilized in prehistoric land use activities.

The range attributed to aboriginal groups in this area has been compiled from Stewart's (1939, 1941) and Kelly's (1934) ethnographic and ethnohistoric work among bands of Northern and Southern Paiute, respectively. The period considered is roughly the mid-nineteenth century. The range estimates (Tables 4 and 5) were computed by gridding maps available in Stewart (1939, 1941) and Kelly (1934) that show the estimated areal extent of activities of each band. The area attributed to each band was summed and square kilometers calculated from that sum. Stewart (1939:146147) estimated the area of each band to the nearest 100 square mile and, therefore, the estimates in Table 5 may vary somewhat from his figures. Stewart, however, does not describe how he estimated those figures.

Precipitation data were taken from that available in the 1936 *Climatic Summary of the United States*, compiled by the United States Department of Agriculture Weather Bureau. Weather stations located within the range attributed to each group as delineated on

Stewart's and Kelly's maps were then used to compute the mean annual precipitation for that area. This set of data was chosen because of the availability of precipitation information from statistics broadly distributed in this study area during the late nineteenth and early twentieth centuries.

The mean of the ranges for twenty-two Northern Paiute bands and fourteen Southern Paiute is more than 10,000 square km. Table 6 represents range and population estimates made by Julian Steward (1938) for groups in the Great Basin. The population density of those using the Great Basin was of primary interest to Steward. The mean of the areas he used for making density estimates (9,384 sq km) is remarkably similar to the data compiled for the Southern Paiute (10,314 sq km) and Northern Paiute (10,645 sq km) bands. These data suggest that, in general, small human groups employing little or no horticulture utilized thousands of square kilometers in their range of activities, either annually or thoughout the lifetime of group members (cf. Binford 1983a:205-206; Fowler 1982:124-125; Plog and Powell 1984:212).

Table 4. Southern Paiute range. Derived from Kelly (1934) and U.S. Department of Agriculture Weather Bureau (1936).

Band	Range Size[1] ca. 1850 (km^2)	Average Annual Precipitation (inches)	Range of Stat. Elevations (feet amsl)	Max. Range of Years for Precipitation Data
Las Vegas	29,836.54	4.59	784 -3,445	1885-1930
Moapa	11,753.79	5.42	1,400	1895-1930
Paraniga	6,070.64	6.15	4,130	1921-1930
Panaca	13,562.06	8.47	4,407-6,110	1877-1930
Beaver	10,849.65	9.84	4,962-7,318	1885-1930
Cedar	9,041.38	12.93	3,800-5,970	1897-1930
Gunlock	1,808.28	19.02	6,400	1904-1920
St. George	2,066.60	10.94	2,800-3,800	1890-1930
Uinkaret	2,839.38	11.96	3,800-5,000	1912-1930
Panguitch	3,358.23	9.77	6,500-7,000	1901-1930
Kaibab	14,595.36	16.43	3,142-8,400	1875-1930
Kaiparowits	14,337.04	11.38	4,000-8,060	1895-1930
San Juan	15,112.01	7.31	3,142-5,800	1897-1930
Chemehuevi	9,170.54	(no data available)		

[1]Mean range size = 10,314.39 km^2

Table 5. Northern Paiute range and density. Derived from Stewart (1939; 1941) and U.S. Department of Agriculture Weather Bureau (1936).

Band	Range Size[1] ca. 1850 (km^2)	Average Annual Precipitation (inches)	Range of Stat. Elevations (feet amsl)	Max. Range of Years for Precip-itation Data	Km^2 per person (from Stewart 1939:146-147)
Hunipui	20,189.69	17.26	2,400-6,250	1891-1930	116 (1870-90)
Wada	31,952.38	10.57	2,156-5,000	1889-1930	135 (1870)
Yahuskin	15,800.63	10.16	4,200-4,888	1892-1930	
Koa'agai	23,876.50	15.49	2,114-5,500	1864-1930	29.8 (1862)
Kidu	13,167.19	12.98	4,950-5,730	1868-1930	87.8 (1873)
Tsoso'odo	8,953.68	7.73	4,146-4,300	1915-1930	
Agaipanina	6,320.25	5.86	4,850	1901-1926	
Atsakudokwa	6,320.25	11.34	4,700	1866-1919	45.1 (1870)
Sawawaktodo	7,900.31	5.48			
Yamosopo	6,144.69	8.90	4,300-4,650	1894-1930	
Kamo	8,251.44	5.15	3,980-4,725	1912-1930	53.2 (1859)
Makuha	7,198.06	6.67	4,375-4,392	1870-1930	
Wada (south)	2,457.87	10.57			
Tasiget	2,984.56	6.09	4,198	1913-1930	5.1 (1859)
Kuyui	5,442.43	5.41	4,150-4,190	1870-1930	5.6 (1859)
Kupa	11,236.00	3.75	3,977-4,072	1870-1930	14 (1866)
Toe	13,342.75	6.02	3,965-6,594	1877-1930	16.7 (1866)
Agai	5,442.43	5.87	4,124-4,125		10 (1859)
Tovusi	5,618.00	5.52	4,200-4,800	1860-1930	6.8 (1859)
Pakwi	5,442.43	4.08	4,200-6,180	1884-1930	54.4 (18?)
Washo	10,358.19	21.30	4,532-8,000	1870-1930	
Tago	15,800.63	(no data available)		73.8 (1890)	

[1]Mean range size = 10,645.45 km^2

Table 6. Range and density data for aboriginal groups in the Great Basin. Compiled from Steward (1938).

Aboriginal Group	Range Size[1] ca. 1860-1880 (km^2)	Population	Population Density 100 km^2
Owens Valley Paiute	5,503.75	1,000	18.17
Deep Springs Valley	647.50	23	3.55
Fish Lake Valley	2,564.10	100	3.90
Saline Valley	2,797.20	65	0.91
Death Valley	3,263.40	42	1.29
Beatty	3,367.00	29	0.87
Belted Mts.	3,367.00	42	1.26
Las Vegas	24,475.50	332	1.37
Reese River Valley	2,331.00*	625	27.08
Kawich Mts.	5,244.75*	105	2.02
Little Smoky Valley	4,403.00	96	2.20
Railroad Valley	5,827.50	250	4.33
Antelope Valley	2,331.00	78	3.38
Spring and Snake Valley	6,241.90	378	6.12
Gosiute	25,900.00	800	3.12
Diamond Valley	4,014.50	400	10.06
Ruby Valley	3,108.00	420	13.65
"Bruneau"	12,432.00*	475	3.86
"Boise"	9,324.00*	250	2.71
Ft. Hall Shoshoni	64,750.00	1,100	1.87
Utah Lake Ute	5,180.00*	550	10.60

Mean range size = 9,384.43 km^2; *individual entries are means

If the large range used by these groups is a reflection of the net above-ground primary productivity and resource accessiblity, then we should expect that the mean annual precipitation in these areas will vary inversely with the size of each group's estimated range. The Paiute data was analyzed to evaluate this assertion. A bivariate linear regression of Southern Paiute band range and mean annual precipitation yields a negative correlation coefficient (r) equal to -.47 ($n=13$, $F_{1,11}=3.10$, $p > .10$, see Figure 17). This suggests that 22% of the variability in range size is accounted for by the variation in mean annual precipitation. In contrast, an identical analysis of the range size of Northern Paiute bands yields a positive correlation coefficient (r) of +.47 ($N=21, F_{1,19}=5.36, p < .025$, see Figure 18), suggesting an opposite association between range size and mean annual precipitation. Combined data for the Southern and Northern Paiute provides no evidence for a systematic relationship between aboriginal home range size and precipitation (Figure 19).

This inverse relationship between range size and precipitation among the Southern Paiute is not significant in terms of probability statistics. More important, however, is the ability of one independent variable—mean annual precipitation—to account for 22 percent of the variability in the range size of these bands (Birdsell 1978).

The Great Basin environment used by the Northern Paiute is characterized by a spatial and temporal incongruity of resources useful to these groups. Unearned water, a variable filtered out in the data used by Birdsell (1953), must be considered with respect to the Great Basin range estimates. The resource structure in this area is influenced directly by the topographic relief, where the range of elevation may extend over 8,000 ft. Snow accumulation in the mountain ranges obviously increases runoff that results in rivers, lakes, and springs. These water sources become, in effect, clumped resources affecting the size of the range used by aboriginal groups. For example, current topographic maps of the area attributed to Northern Paiute bands show a number of major permanent river systems and numerous lakes within the ranges utilized by many of these groups. D.H. Thomas (1981; Thomas and Bettinger 1976) suggests that these water sources should be perceived, in general, as either a point resource (i.e., potholes and springs) or a linear resource (e.g., rivers or lake margins) that strongly influences the mobility and residential organization employed by aboriginal groups in this area. In the Great Basin it is argued that residential sites (i.e., campsites) are located with respect to the availability of water, and for the most part, at the expense of other resource considerations.

The Island-in-the-Sky, formed by the confluence of the Colorado and Green Rivers, is an expanse of elevated land sandwiched between two linear resources. Canyons carved by these rivers, however, require that "optimal positioning" of residential sites not be along rivers per se, but located on the White Rim above the river or plateau forming the Island. Springs, potholes, or tanks within this elevated area form point resources at which limited residence can be considered feasible. The annual amount and seasonal nature of rainfall in the study area determined the utility of these water sources. Residences near these locations should be expected to be of a short-term nature, conditioned by annual and seasonal precipitation, consequent availability of plant resources, and accessiblity of this water for game.

The extent of land used by prehistoric groups in the study area probably varied over the long term, in part, due to the interactions of fluctuations in resource density and dispersion and climatic changes. Numerous examples of human range contraction, expansion, and drift are documented in response to these variables (Hill 1969) and to changes in population density.

Alterations in the adaptive response to conditions of the physical environment result from population density change. An increase in the species density in an area means a reduction in the amount of area and resources available to support each individual (Cooper 1978; Davies 1978:341-345). Range size, therefore, may also be influenced by the density of the local population, especially where emigration is not a viable option. Human adaptive responses to these changing conditions can vary. The most visible responses in arid and semi-arid environments prehistorically are within the complementary realms of subsistence practices, i.e., food choice and spatial organization. Consequently, it is useful to examine changes in aboriginal population density, subsistence, and spatial organization in the study area through time.

We find that there is a relatively weak, direct relationship between the number of square kilometers of home range per person and mean annual precipitation for the Northern Paiute (Figure 20). A linear

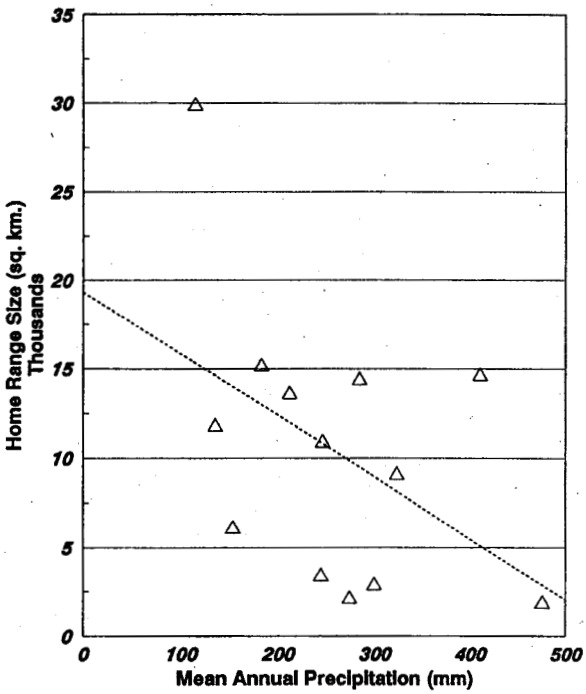


Figure 17. Home range and precipitation, Southern Paiute.

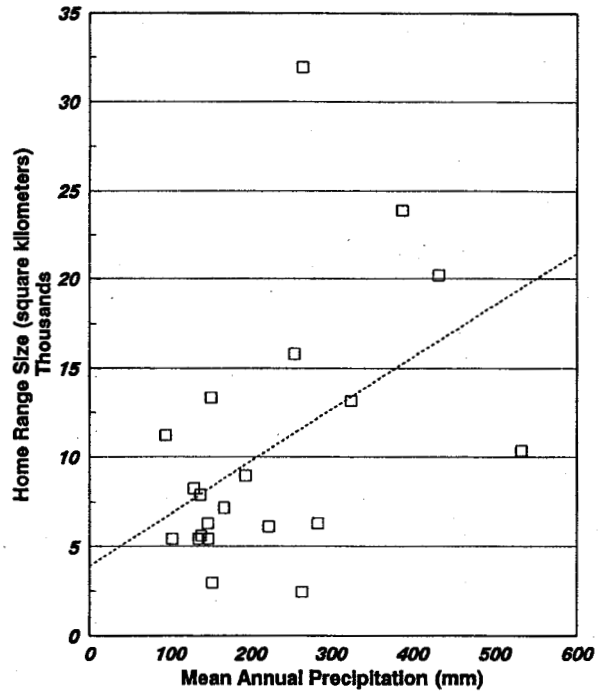


Figure 18. Home range and precipitation, Northern Paiute.

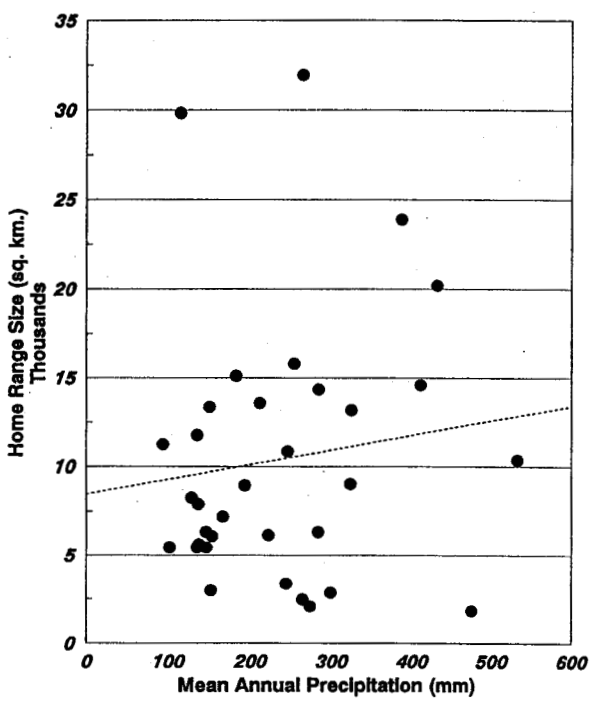


Figure 19. Home range size and annual precipitation, Northern and Southern Paiute.

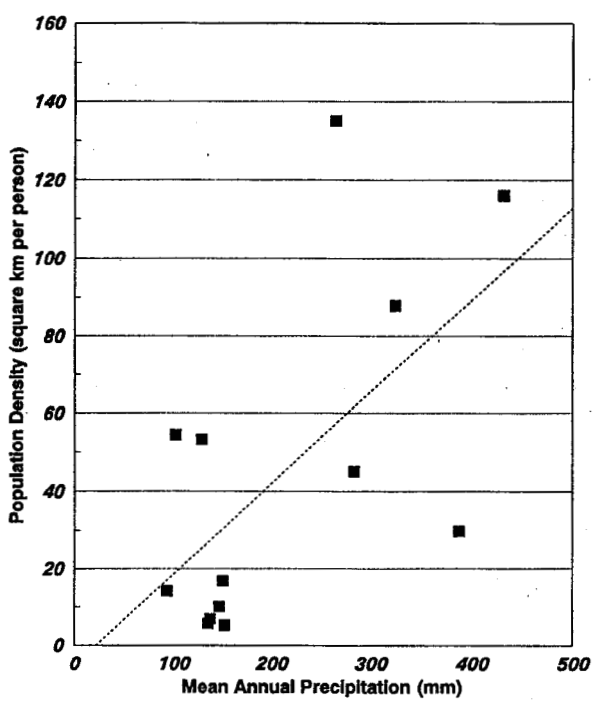


Figure 20. Population density and precipitation, Northern Paiute (Kelly 1934).

regression of this data provided a correlation coefficient (r) equal to + 0.50 ($R = 0.25$; $F_{1,11} = 3.67$, $p > .10$). In actuality, however, this means that human population density and mean annual precipitation are inversely related, since greater values of "y"are, in fact, lower measures of population density. Readers can refer to the previous discussion of Northern Paiute home ranges size and mean annual precipitation in order to assess this population density observation.

PREHISTORIC OVERWINTERING STRATEGIES

The second major component of this land use model includes a set of ecologically-based expectations regarding aboriginal winter home range(s). Fall and winter land use included high logistical mobility within collapsed home ranges centered on high plateaus and/or isolated mountain ranges such as the Uncompahgre Plateau, Mesa Verde, or the La Sal (Figure 21), Abajo, or Henry mountain ranges. Winter herds of ungulates were hunted during the winter on a "day-to-day" basis, and plant foods were retrieved from caches at lower elevations.

Since the study area is situated within a cold desert, we can expect that aboriginal groups faced significant ecological constraints. Marked declines in temperature and dramatic shifts in precipitation occur at the end of the growing season. Plant production decreases sharply at this time over most of the region. As a result of these environmental fluctuations, aboriginal groups were confronted with a significant adaptive problem. Binford (1980) has discussed the role of unstable thermal environments and the "overwintering problem" that they pose for hunter-gatherers. He (1980) suggests that there are three basic adaptive responses that can be expected: 1) utilization of resident animal populations that have solved this environmental problem; 2) specialized procurement and storage of seasonally aggregated animal resources, e.g., anadromous fish, sea mammals, caribou or bison; and 3) plant resource procurement and storage.

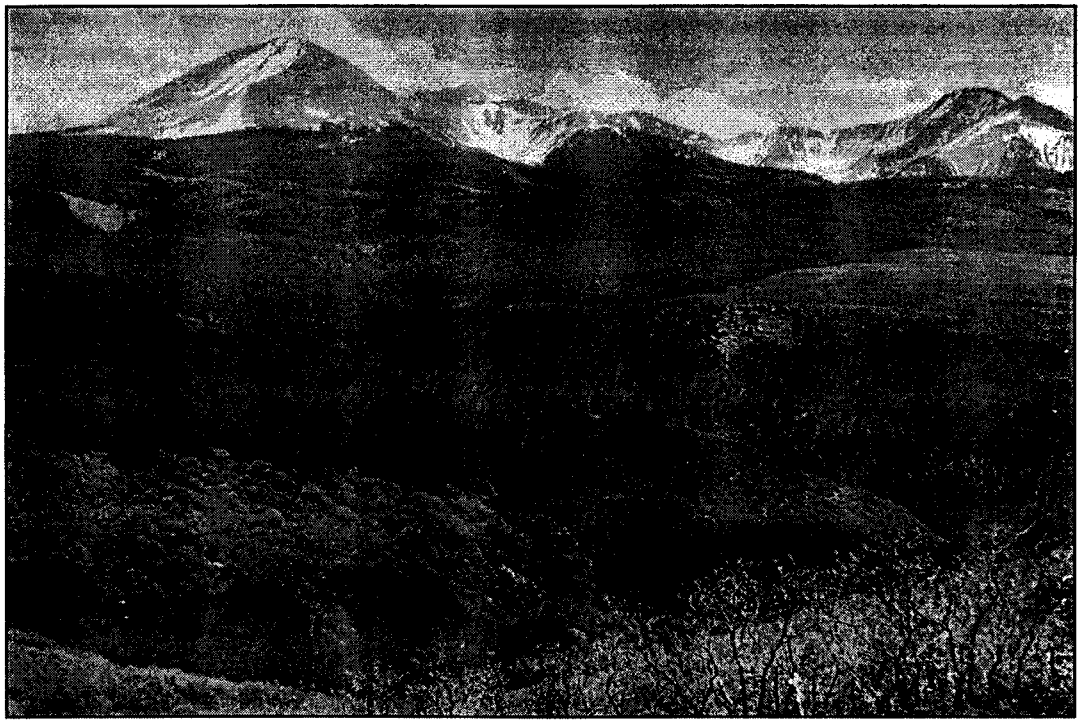


Figure 21. View of the La Sal Mountains looking east toward Mt. Peale.

Given the availability of large ungulate populations in the uplands, we expect that prehistoric hunter-gatherers and early cultivators in southeastern Utah depended heavily on these animals in order to solve their overwintering problem. Mule deer, elk, and bighorn sheep had developed a set of morphological, physiological, and behavioral responses to limitations imposed by low temperatures and snowfall on their mobility, foraging, and reproductive strategies. If aboriginal groups relied intensively on such ungulate populations during the nongrowing season, then we might expect to observe a number of strong interrelationships between winter climate, resident ungulate herds, and hunter-gatherer populations. A major portion of the following discussion, therefore, focuses on the determinant relationships between winter climate and ungulate survival.

ENVIRONMENTAL BACKGROUND

Although initially it may seem counterintuitive, there are sound ecological reasons to assume that prehistoric hunter-gatherers may have established their winter home ranges in the snow-covered upland plateaus and isolated mountain ranges. For this reason, this discussion will focus specifically on isolated mountain ranges or "moisture islands" that punctuate the desert landscape in the American Southwest, particularly the Colorado Plateau in southeastern Utah. Ecologists and meteorologists have referred to mountain ranges in the Great Basin and the American Southwest as "rainy islands" (Bailey 1981), "alpine islands," or "mountain islands" (Bender 1982). Erlich et al. (1988) have referred to such mountain ranges in the Great Basin as "isolated islands of moist montane habitat in a sea of desert."

In southeastern Utah, for example, three isolated mountains ranges created by laccolithic intrusions rise to elevations between 3,462 meters (11,360 feet) and 3,877 meters (12,721 feet). These higher elevation settings exhibit cooler temperatures, increased precipitation, and decreased evaporation.

As Pianka (1983:27) states,

> Ascending a mountain is, in many ways, comparable to moving toward a higher latitude: Mountains are usually cooler and windier than adjacent valleys and generally support communities of plants and animals characteristic of lower elevations at higher latitudes (300 meters of elevation corresponds roughly to 160 kilometers of latitude).

We find that, "In a world context, the dry lands of the United States are located in higher latitudes and stand at higher altitudes than is typical of many other arid regions of the world" (Bailey 1981:13). Furthermore, a number of isolated fault block and laccolithic mountain ranges rise above the desert floor, creating large, rugged expanses of unusually moist, cool climate. These "moisture islands" capture precipitation from both high pressure storm systems from the Gulf of California in summer or the Pacific coast in winter. These highland areas are characterized by a series of parallel or concentrically-arranged, heavily vegetated zones, including pinyon-juniper (1,524-2,134 meters), mountain brush (1,981-2,438 meters), montane fir-aspen (2,042-2,743 meters), and sub-alpine spruce-fir (2,850-3,450 meters) communities. Primary productivity associated with these moisture islands is substantially greater than the surrounding shadscale, big sagebrush, and blackbrush communities that occur below 1500 meters amsl. Plant production in the La Sal Mountains of southeastern Utah, for example, ranges from 40 to 240 grams dry forage/sq m/year; These moisture islands sustain relatively large resident populations of large ungulates, including Rocky Mountain mule deer (Odocoileus hemionus), elk (Cervus canadensis), and bighorn sheep (Ovis canadensis).

Optimal Foraging Considerations

In the present study, optimal foraging theory provides us with a set of expectations regarding diet composition for aboriginal peoples in the study area. Initially, cost-benefit ratios for various food resources can be calculated based on the quantity of energy required for search, pursuit/capture, and processing, in relation to the energy derived from certain resources.

Simms (1984a, 1987) has calculated return rates for a number of wild plant and animal resources in the Great Basin. He made use of ethnographic data, recent nutritional analyses, and plant harvesting and processing experiments in order to obtain these values (Figure 22). Handling costs include pursuit time and processing time. Pursuit time for plant resources, in this

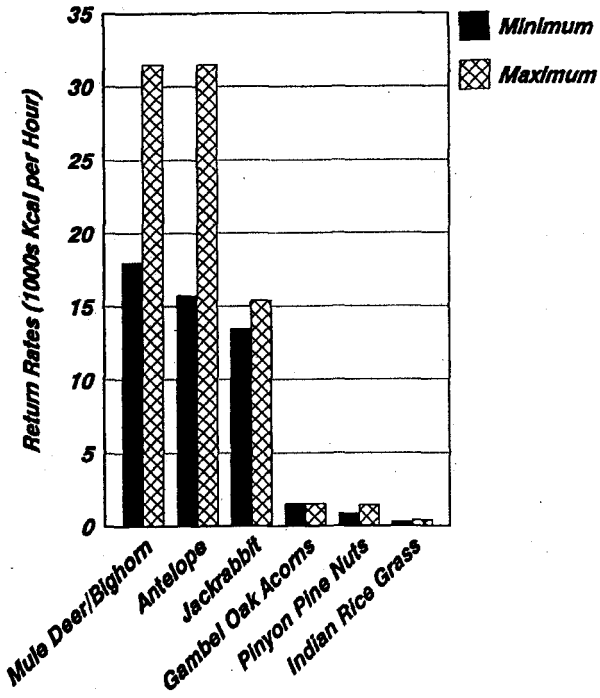


Figure 22. Return rates for select food resources.

case, equals harvest time following the location of a given resource patch; whereas for animals pursuit time equals postencounter procurement time. Processing time for plants includes the time spent parching and/or winnowing the resource; for animals processing time includes the period spent gutting, skinning, and rough butchering the animal (Simms 1984a:76-92).

Simms (1984a) used field experiments in order to calculate the processing times for twenty-four wild plants, including cattail, gambel oak acorns, pine nuts, wild rye, Indian rice grass, shadscale, and so forth. Both pursuit and processing times for animal resources were calculated based on data provided by contemporary hunters. These estimates of return rates must be accepted with some caution; pursuit and processing costs for these resources may change if they were based on energy costs versus time costs. Simms (1984a) demonstrates that animal resources, particularly terrestrial mammals exhibit higher return rates than plants resources. Minimal return rates for both mule deer and bighorn sheep, for example, are more than twelve times greater than the maximum return rates for Gambel oak acorns or pinyon nuts. Return rates for large mammals, e.g., mule deer, bighorn sheep, and antelope, exceed those for small mammals, e.g., ground squirrels, by an order of from 5 to 10.

Relevant Ungulate Ecology

The most severe environmental constraints imposed on the ungulates of North America coincide generally with the onset of winter. Edwards (1956:159) states, "It is long established that 'severe winters,' or 'hard winters,' cause fluctuations in ungulate populations.... Published accounts of ungulate mortality due to severe winters or deep snow involve a wide range of species in a large geographic area."

Telfer and Kelsall (1984:1828) emphasize that,

> Only in recent decades have ecologists begun to evaluate the role of snow cover in winter survival of animals and plants.... Studies of snow as a factor in the ecology of ungulates... (show) ... that many of the morphological, behavioral, and physiological charactersitics observed among northern ungulate species were adaptations that increased survival in snow.

Winter precipitation imposes a number of very significant ecological constraints on ungulates, as well as other animal populations. The following discussion reviews several of these constraints, including the effects of snow accumulations on ungulate morphology, fecundity, mortality (including predation), land use (including winter range and home range), and diet and nutrition. Several of these topics will be discussed with respect to ungulates in general. Other adaptive constraints will be examined with specific reference to Rocky Mountain mule deer. Mule deer will be discussed in greater detail, not only because they have been intensively studied by wildlife ecologists, but also because they were a significant food resource for many aboriginal groups in western North America.

Ungulate Snow Coping Abilities. Telfer and Kelsall (1984) have rank ordered the snow coping ability of a number of North American ungulates (Table 7). This ranked classification is based on a morphological index that includes measures of mean chest height (cm) and mean foot loading(g/sq cm). In addition, behavioral characteristics were also used in order to

Table 7. Snow coping abilities for North American ungulates (Telfer and Kelsall 1984:1831, Table 3).

Species	Morphological Index/200	Behavioral Index/30	Mean Snow Coping Index
Caribou	.77	.87	.82
Moose	.70	.63	.67
Dall sheep	.61	.57	.59
Wapiti	.59	.60	.60
Bighorn	.57	.53	.55
White-tailed deer	.56	.70	.63
Bison	.48	.50	.49
Antelope	.41	.43	.42

assess the winter coping abilities of mammals. These characteristics include ability to feed on above-ground food, use of trails, rooting/digging ability, migration (horizontal and/or vertical), selection of most suitable winter ranges, and techniques of locomotion (Telfer and Kelsall 1984:1829). Winter snow severity was related to depth and crust.

They (1984:1831) found that,

> The regular increase in mean adaptation index values for regional faunal groupings ... from the short-grass plains species to the boreal forest corresponds in a general way to the degree of severity of snow conditions. Although the central Rocky Mountains and the northern mountains have heavy snowfalls, the rough topography provides slopes where snow usually blows off or melts due to inclination toward the sun (Stelfox and Taber 1968). In local situations valleys may lie in the precipitation shadow of mountain ranges so that the valley bottoms receive minimal snowfalls. Ungulates move to the shallow-snow locations for wintering (Stelfox and Taber 1968).

Telfer and Kelsall (1984:1831) propose that the different snow coping abilities of ungulates offer greater insights into the dynamics of fauna shifts during the Little Ice Age ca. 1300-1850. At this time the dominant ungulates in Nova Scotia, for example, shifted from moose and white-tailed deer to moose and caribou fauna. With milder winters after the mid-1800s, we find that the fauna shifted once again toward a moose/white-tailed deer dominated large mammal population.

The unusually high coping index exhibited by caribou can be attributed, in part, to the high Mean Foot Loading value related to the larger hoof size produced by the large dewclaw. "Caribou feet with their large dewclaws thus represent retention of a primitive characteristic, compared to the feet of the more specialized antelope. Caribou may have diverged from the rest of the Cervidae in the early Pleistocene by adapting to the snowy environment" (Telfer and Kelsall 1984: 1831).

On the other hand, white-tailed deer exhibit relatively low morphological indices for snow coping ability, yet they can be found in areas that exhibit severe winter conditions. They appear to be able to respond to such conditions via increased behavioral flexibility. Their behavioral index (0.70) is greater than their morphological index (0.56) (Telfer and Kelsall 1984: 1831).

The snow coping indices developed by Telfer and Kelsall (1984) can also be seen to possess significant implications for sexual dimorphism exhibited by North American ungulates. "Sexual dimorphism in chest height of adult ungulates ranged from 0.8 percent for moose to 9.5% for white-tailed deer. Dimorphism in foot loading had an even greater range, from 4.6% for moose to 27.2 percent for bison" (Telfer and Kelsall 1984:1830).

Bison females are much lighter than males and therefore have greater advantage in crusted snows of the plains. They can operate at lower energetic costs than their male counterparts. Bison save foraging energy through trail-making behavior for feeding purposes (Telfer and Kelsall 1832).

Telfer and Kelsall (1984: 1833) state that,

> Use of deeper or softer snow by different age and sex groups could have considerable survival value. Usually a gradation of depth, and of hardness and density, occurs in the snow cover of a region based on topographic position and nature of vegetative cover. Differing ability to use snow distributes individuals of the species more widely, thus reducing pressure on the forage available to each animal. In most ungulate species, mature males separate from juveniles and from females with young.

Snow Cover and Ungulate Fecundity. Mech et al. (1987) have demonstrated a set of relationships between winter snowfall and the fecundity of white-tailed deer and moose populations. These ungulates experience a pronounced period of weight gain during the spring, summer, and fall; considerable weight is then lost throughout the winter. The degree of weight loss is a function of the length and the severity of winter. In general, winter severity involves both temperature and precipitation. The depth and duration of snow, the extent of "crusting" or ice formation, and the duration of freezing and below freezing temperatures all contribute to an index of winter severity. Snowfall accumulation and crust formation will impede the movements of ungulates and will limit access to adequate forage. Such climatic conditions, then, ultimately determine the extent of the annual weight loss and the ability of the animals to recover during the rest of the year.

Deer and moose fecundity depends considerably on the degree of winter malnutrition and warm season recovery. Furthermore, ungulates are gravid during winter and spring. For this reason, winter and spring weather potentially has a greater effect on fetal development, weight and survivability of offspring, and ultimately the degree of annual population (Mech et al. 1987:616).

Mech et al. (1987) hypothesized that snow acccumulations in previous, consecutive winters would have an inverse, cummulative effect on future deer and moose productivity and population changes. These investigators used linear regression analyses in order to demonstrate a causal relationship between previous winter climatic conditions and changes in ungulate population. Fawn-to-doe ratios for mule deer and lamb-to-ewe ratios for bighorn sheep have been shown to be inversely related to late winter and early spring snow depth and water content.

Mech et al. (1987:624) propose that, "While several explanations for the cumulative winter effect are conceivable, the simplest would be that of a winter-to-winter carryover of nutritional influences." They (1987:627) suggest that investigators reexamine "... the assumption of full nutritional recovery during each summer ...."

SNOW COVER AND WINTER MORTALITY

Edwards (1956:165) states, "...that deep snows have been recognized as a factor in ungulate mortality for a long time..., [but] have been regarded as an occasional phenomenon rather than [a] major recurring condition ...." He (1956) also emphasized that variation in the distribution of snowfall had not been adequately taken into account in wildlife management studies.

He (1956:166) states,

> Consideration of deep snow periods also casts some doubt upon past analyses of ungulate-range relationships. Two ranges which appear to have the same resources in autumn, and therefore might be expected to winter equal numbers of animals, will in reality support very different populations if one has shallow snow, the other deep snow.... Again, in mountainous terrain at least, years of deep snow tend to concentrate ungulates at the lower elevations.

Picton (1979:117) found that climatic conditions accounted for approximately 70 percent of the variability in fawn survival. Warm, dry winters favored increased production and survival of fawns. Mech et al. (1987:616) state,"Furthermore, because ungulates are gravid during the winter and spring, winter and spring weather potentially has a great effect on fetal development and weight and survivability of offspring ...."

Winter severity can also be related systematically to variable levels of predation on ungulate populations. Nelson and Mech (1986:471) state, "Wolves capture more prey during severe winters with deep snow .... Increased wolf kill of moose (*Alces alces*) has been related to increasing snow depths .... "These investigators (1986:472) found that there was "... a significant positive relationship between January-April wolf predation rates and January-April snow indexes, which explained 51 percent of the variation in predation rate (R squared = 0.51; $P<0.02$)."The snow index was equal to total weekly snow accumulations (in feet of snow) and the temperature index was based on the average monthly mean minimum temperature.

Snow accumulation varied significantly as a component of winter severity. Nelson and Mech (1986:472) comment that, "Mean weekly snow depths were 1.7x deeper in severe winters than in mild winters during January-March, but 2x as deep in April." Wolf predation levels, in turn, were conditioned by snow depths. The authors (1986:472) state, "... wolves tend to kill more deer during severe winters...[T]he kill rate is more directly related to snow depth than to temperature... [T]he effect of snow depth is most pronounced in late winter (April) during severe winters when snow depth averages 2x that in milder winters."

Snow significantly affects the escape capabilities of deer. It restricts mobility and increases energy costs—reduces deer fat reserves (Mattfeld 1974; Parker et al. 1984). Also, cold temperatures deplete deer fat reserves due to increased maintenance costs due to heat losses. "The cumulative effect of this energy drain, especially in late winter, decreases deer physical condition and predisposes them to wolf predation" (Nelson and Mech 1986:472).

Forest Cover Type on Snowfall Accumulation. It is important to point out that snow accumulation in mountainous areas can be affected by vegetative cover. Edwards (1956:165) mentions that forest cover offsets the effects of deep winter snows on Vancouver Island. Kirchoff and Schoen (1987) found that various characteristics of forest cover were inversely related to snow accumulation. Snow cover in forested areas is affected by forest cover type. Snow accumulation was limited by the presence of coniferous species, as well as the age of the particular forest. Kirchoff and Schoen (1987:28) state, "Low snow depths observed in high-volume, old-growth stands are attributed to the large-diameter limbs and deep crowns of older trees." Much of the winter snowfall in such forested areas never reaches the ground. These investigators (1987:31) point out that, "Snow held aloft in the canopy exposes increased surface area to precipitation, wind, and ambient air temperatures, resulting in increased rates of melting ...."

As Schwab et al. (1987:342) point out, however,

> These many sources of environmental and biological variation produce complex relationships among canopy cover, snow depth, and availability of browse on big game winter ranges. Our study identified a portion of that complexity and demonstrated that browse on moose winter ranges in northcentral British Columbia is relatively more available in open areas. Increasing browse burial corresponded with increasing canopy cover during both the snow accumulation and snow melt periods.

Case Study: Rocky Mountain Mule Deer. The following discussion deals with ones species of ungulate—mule deer (*Odocoileus hemionus hemionus*). We are fully aware that prehistoric and historic populations exploited a number of other mammals, including antelope, bison, elk, and bighorn sheep. A number of the interrelationships between winter climate, i.e., snowfall and minimal temperatures, and mule deer physiology, demography, and behavior, however, can be extended to other ungulates. This specific information regarding mule deer is offered to aid archeologists in better understanding this species as well as the general determinant relationships outlined in the wildlife ecology literature.

The Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) is one of the most ubiquitous large ungulates of the Colorado Plateau Shrubland and Forest Province. Wallmo (1981:16-17) provides a succinct description of this biotic province,

> A circle drawn to include northern Arizona, eastern Utah, southern Wyoming, western Colorado, and northern New Mexico encompasses the area of highest general elevation in North America. Most of it is more than 1,500 meters (approximately 5,000 feet) above sea level, and mountain ranges throughout rise to more than 3,000 meters (approximately 10,000 feet). It has a highland climate, somewhat comparable to that of the northern Rockies, but is isolated by an intervening strip of midlatitude semiarid climate in Wyoming. Because of its elevation, the area intercepts residual moisture in eastward-moving air masses. Local relief results in a great diversity of local climates. Precipitation is distributed rather evenly throughout the year, with variations reflecting proximity to surrounding climatic regions. Increased precipitation occurs at high elevations owing to the effects of mountainous topography.
>
> The province includes a profusion of vegetation types, with five general forms most significant to deer and habitat management. They are sagebrush, juniper/pinyon woodland, mountain shrub, montane forest, and subalpine forest ....

Mule deer are extremely flexible with respect to physiological and behavioral responses to this heterogeneous environment. This large mammal make makes use of a broad range of habitats in this region that are defined on the basis of vegetation and climate. These habitats include 57 to 58 of Kuchler's 60 total vegetative types west of the 100th meridian (Wallmo 1981:10). The Rocky Mountain mule deer exhibits considerable climatic tolerance (Wallmo 1981:10). Climate within the mule deer habitats ranges from an average January temperature equal to -15 degrees (5 degrees F) to 30 degrees C (86 degrees F), and mean annual precipitation ranges from 10 cm (4 inches) to 500 cm (200 inches) (Wallmo 1981:22). Thermoregulatory responses of the mule deer enable it to withstand wind chills between 75-100 degrees C (100-150 degrees F) below normal body temperature or heat stress produced by ambient temperatures greater than 10 degrees C (50 degrees F) above normal body temperature (Wallmo 1981:22).

Short (1981:99) comments,

> Mule deer are small ruminants with limited ability to digest highly fibrous roughage. They are physiologically adapted to enter the winter season of food scarcity in maintenance status and to be in a productive condition during the warm season when forage frequently is abundant, green, and lush. Deer have physical, behavioral, and physiological adaptations that allow them to feed on vegetation as varied as that found in alpine meadows and in the Sonoran desert ... and to cope with climates ranging from the severe winters of the northern Rocky mountains to the sweltering summers of southwestern deserts.

Mule Deer Diet and Nutrition. As mentioned, mule deer are small ruminants. Their diet consists of shrubs (60 percent), forbs (28 percent), and grass (13 percent) (see Table 8). Shrubs dominate the diet throughout summer, fall, and winter. Grasses and forbs make up the remaining forty percent of the annual diet;

their relative contributions are equivalent in winter and spring but vary markedly during summer and fall (Table 9). Basal metabolic rate equals approximately 70 kcal/kg body weight/day in order to maintain a core temperature equal to 30 degrees C (Anderson in Wallmo 1981:72). This basal metabolic rate is reduced during winter and is related to the length of the photoperiod by way of the endocrine system (Anderson 1981).

Water requirements for mules deer equal 0.5 kg of water for each kilogram of fresh succulent browse. Short (1981 in Wallmo 1981:110-111) states, "Water intake by deer seems to be related to dry matter intake ... so that water requirements probably are greater in late spring, summer, and early autumn when food consumption is greatest." In winter, snow is utilized as a source of moisture by mule deer.

The foraging areas utilized by the mule deer at Mesa Verde included the pinyon-juniper community that covers approximately 50 percent of the park and the mountain brush community. The mountain brush community provides better browse and is a better habitat for deer. This transitional community is maintained by fire and consists of a patchwork of Gambel oak, Utah serviceberry, black sagebrush, and other browse species. Grasses and forbs are abundant in the openings between the dense shrub thickets (Mierau and Schmidt 1981: 5-6). Browse cover was generally low throughout the pinyon-juniper; cover relatively high near edge of community, but dropped to 2-3 percent on the forest's interior (Mierau and Schmidt 1981:31).

Mule deer apparently reduce their "... food consumption during late autumn and winter and remain in a maintenance state rather than a production state at this time"(Short 1981 in Wallmo 1981:115). Adult males exhibit their highest energy-intake levels during the summer, but reduce food ingestion in autumn and winter (Short 1981 in Wallmo 1981:115). Does also reduce food consumption rates during the fall and winter, but they exhibit less dramatic weight loss than bucks during this same period (Short 1981 in Wallmo 1981:116).

Table 8. Summary of dietary composition based on season (data from Van Dyne et al. 1980:303, Table 4.5;305, Table 4.6).

Species	Season	Grass %	Forb %	Shrub %
Pronghorn	Spring	29 ± 23	43 ± 22	28 ± 22
	Summer	7 ± 7	70 ± 24	23 ± 27
	Fall	18 ± 26	34 ± 21	48 ± 29
	Winter	16 ± 24	21 ± 20	63 ± 33
	Average	15 ± 21	42 ± 28	43 ± 32
Mule deer	Spring	24 ± 25	28 ± 19	48 ± 27
	Summer	4 ± 4	42 ± 31	54 ± 23
	Fall	9 ± 8	22 ± 23	68 ± 25
	Winter	17 ± 19	20 ± 21	63 ± 28
	Average	13 ± 17	28 ± 26	59 ± 30
White-tailed deer	Spring	12 ± 12	39 ± 17	49 ± 22
	Summer	4 ± 4	36 ± 27	60 ± 25
	Fall	9 ± 16	19 ± 20	72 ± 24
	Winter	11 ± 11	12 ± 13	77 ± 20
	Average	10 ± 11	30 ± 23	60 ± 27
Bison	Average	91 ± 10	5 ± 4	4 ± 8
Elk	Average	69 ± 26	14 ± 19	17 ± 22
Bighorn sheep	Average	65 ± 16	14 ± 12	21 ± 16

Table 9. Dietary composition of mule deer, elk, and bighorn sheep in western North America (data from Van Dyne et al. 1980, Appendix 4.2).

Animal Species	Habitat Type	Geographic Location	Season	Diet		
				Grass %	Forbs %	Shrubs %
Mule deer	Pinyon-juniper	Central Utah	Spring	87	6	7
	Sage-oak	Central Utah	Spring	38	17	45
	Currant-snowberry	Central Utah	Summer	8	33	59
	Mountain rangeland	Central Utah	Summer	5	73	22
	Sage-choke cherry	Central Utah	Summer	8	33	59
	Sage-choke cherry	Central Utah	Summer	15	55	30
	Mountain Rangeland Aspen	Central Utah	Summer	4	72	24
	Sage-grass	Central Utah	Summer	0	100	0
	Sage-snowberry	Central Utah	Summer	8	90	2
	Spruce-fir	Central Utah	Summer	5	73	22
	Up. desert shrub, desert grassland/ oak woodland	S-central Arizona	Annual	4	9	87
	Mt. meadow forest sagebrush-bitterbrush	SW Montana	Winter	14	16	70
	Pinyon-juniper	Piceance Basin, Colorado	Annual	2	3	95
	Pinyon-juniper	Piceance Basin, Colorado	Winter (Dec-Mar)	2	1	97

Table 9. Concluded.

Animal Species	Habitat Type	Geographic Location	Season	Diet		
				Grass %	Forbs %	Shrubs %
Elk	Pinyon-juniper/ sagebrush	NE Colorado	Summer	70	3	27
	Mt. range-lands	5 western mt. states	Summer	80	13	7
	Mt. range-lands	5 western mt. states	Autumn	72	17	11
	Mt. range-lands	5 western mt. states	Winter	85	10	5
	Various	Western N. America	Annual	84	8	8
Bighorn sheep	Mountains	Saguache Co. Colorado	Spring	57	10	33
	Alpine meadows	Wyoming	Summer	73	27	0
	Juniper-pinyon/ saltbrush range	S-central Nevada	Autumn	49	50	1
	Mountains	Saguache Co. Colorado	Winter	23	11	66

Fat and Body Composition. Mule deer are characterized by significant fluctuations in body fat that are correlated directly with food intake levels and food composition (Table 10). Anderson (1981) states, "In an evolutionary sense, the annual cycle of body fat may represent a homeostatic adaptation of deer populations to complex seasonal interactions of biotic and abiotic factors characteristic of temperate regions."

Young (1976:699) states, "The food and energy storage levels are especially important in allowing the animal to survive food shortages and stresses associated with competition for mates, territorial defense, gestation, and lactation and to accomplish migrations."

Short (1981:123) states,

The amount of carcass fat in mule deer is greatest in autumn, declines in winter, and is lowest in early spring for bucks and in late spring/early summer for does, when parturition and early lactation occur (Anderson et al. 1972a). Most body fat is deposited during summer and early autumn, after many production demands have been met. At that time, net energy exceeding metabolic requirements can go for fat production. Range

Table 10. Data regarding mule deer carcass fat (Anderson 1981:29).

Sex	Season	Carcass fat (% total wt)
Male	Winter	5.4 ± 1.7
Male	Summer	16.9 ± 7.1
Female	Spring	6.9 ± 3.1
Female	Fall	12.5 ± 3.2

> vegetation is used with greater efficiency for fat production during summer and early autumn because succulent and starchy foods yield increased levels of propionic acid during rumen fermentation, and this favors fat synthesis .... Deer on poor range with limited amounts of easily digested foods do not develop extensive fat deposits. Mule deer become lean when three successive years of drought reduced browse and other useful foods in north-central Colorado (Anderson et al. 1972).

Unlike what we might expect, increased metabolic costs during winter are not offset by increased food consumption. On the contrary, Short (1981 in Wallmo 1981:125-126) states,

> Deer rely on their stored energy reserves at this time to supplement digestible energy available from winter range. Digestible energy intake will be reduced severely if (1) forage on winter ranges is of poor quality because of drought during the growing season, (2) overgrazing by domestic livestock occurred during summer or autumn, (3) overcrowding occurs on deer winter ranges, or (4) winter conditions are particularly severe. Fat stores then act as fundamental rather than supplemental energy sources. Deer with limited fat stores, such as fawns or animals from poor quality summer and intermediate ranges, will deplete reserves quickly and will succumb when insufficient energy is present for maintaining body temperatures and normal body functions.

In contrast to adults, fawns do not have adequate reserves of subcutaneous, intramuscular, and intra-abdominal fat reserves for severe winters. They metabolize protein/muscle instead of fat. As a result, they starve after a shorter period of time (Short 1981 in Wallmo 1981:121).

Deer exhibit their best condition during October, just prior to the breeding season. Females lag one month behind males so that their body weight is lowest in April, versus March. Peak predicted weight losses for mule deer equal 17.2 kg (37.9 lbs) or 19 percent for males and 16.0 kg (35.2 lbs) or 22 percent for females (Anderson 1981:72).

Fat reserves in deer can be measured as percentage of femur or tibia marrow fat, kidney fat, carcass density, percentage of carcass fat, depth of back fat, or bled and eviscerated carcass weights (Anderson 1981:70). Harris (1945) suggested that fat deposits are used in the sequence of subcutaneous, visceral, and femur marrow fat (Anderson 1981:71).

Body fat deposits do not appear to provide much insulation during the winter. Anderson (1981:74) states, "Hence body maintenance, not insulation, probably was the primary function of subcutaneous fat in

that population at 40 degrees 40 minutes north latitude." This body fat is utilized to supplement minimal feeding activity during the winter in this region of North America.

Analyses of carcass fat for mule deer in the Cache la Poudre River drainage of north-central Colorado revealed little contrast between adult males and females (Figures 23 and 24) (Anderson, et al. 1972). Seasonal variation in relative carcass fat was less pronounced in adult females than in adult males (Anderson et al. 1972:589). Kidney fat for adult females was lowest in early June and highest in November; kidney fat was minimal for adult males in April and maximal in late October. Femur marrow fat for adult females was lowest in mid-June to mid-July and highest in in early November to early February; for adult males, femur marrow fat dropped in early May and peaked in July through November (Anderson et al. 1972:589-590). "Thus, each of the three indices for females lagged at least one month behind indices for males in maximal and minimal values"' (Anderson et al. 1972:590).

Reproduction. Mule deer nutrition is central to reproductive success. Short (1981 in Wallmo 1981:121) states, "Quality nutrition is essential for reproduction in mule deer. If nutrition is suitable only for maintenance, then productive functions suffer. Reduced body weights, small antlers, and low reproductive success occur."

Short (1981:122) points out that studies of female nutrition and fawn viability show: (1) well-nourished does lost only about 5 percent of their fawns; (2) does fed deficient diets during the winter lost 33 percent of their fawns; (3) does underfed throughout their pregnancies lost 90 percent of their offspring. And, optimal growth for newly weaned fawns is sustained by 16-17 percent protein foods.

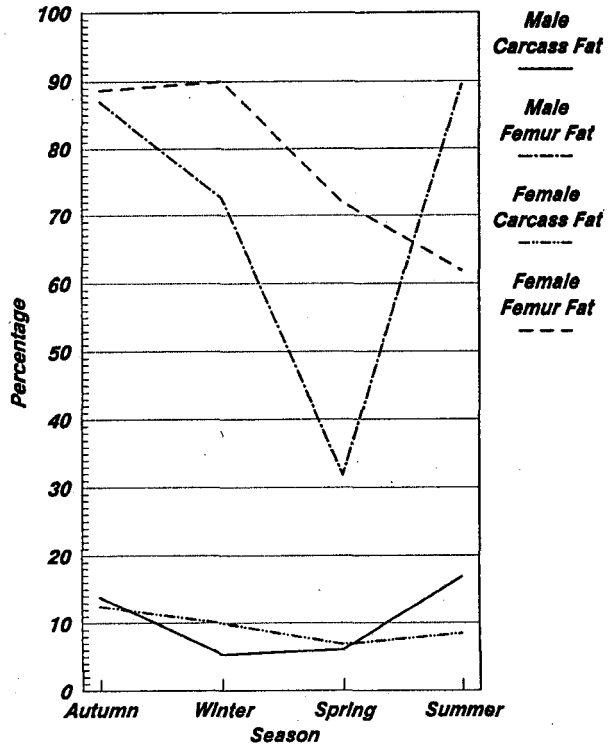


Figure 23. Carcass fat and femur marrow fat, adult male and female mule deer, Cache La Poudre, northcentral Colorado.

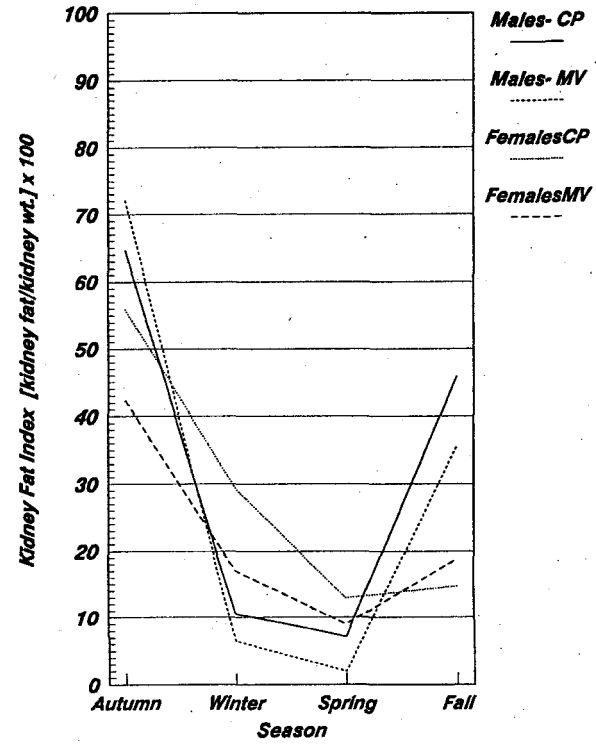


Figure 24. Kidney fat index for mule deer >18 mos. of age, Mesa Verde and Cache La Poudre, Colorado.

Seasonal Movement and Home Range Size. The seasonal movements of Rocky Mountain mule deer have been succinctly described by Wallmo (1981:16-17):

> In winter, high elevations usually accumulate snow to depths that preclude deer use. Seasonal migrations of varying distances are necessary for deer to take advantage of nutrient-rich forage supplies in the mountains in summer and to escape deep snow in winter. But low elevations are hot and arid, with herbaceous vegetation largely dried out by later summer, leaving poor-quality forage for wintering deer. Also, many winter ranges are subject to cold air drainage and very low winter temperatures.

Mule deer in this region begin their migration to the winter range when snowfalls accumulate to 8-10 inches. "Sizable drops in temperature, especially when accompanied by wind or snow, generally delayed or temporarily reversed upward spring movement" (Richens 1967:656).

In Middle Park, Colorado, mule deer"... spend the summer above 9,000 ft. Downward migration begins usually in late October when snow begins to accumulate in the summer" (Gilbert et al. 1970:16). Progressive descent of deer to lower elevations tracks increased snow depths at the higher elevations. Deer in Middle Park tend to range at the highest elevations that winter snows allow (Gilbert et al. 1970:18). During the winter, very few mule deer were observed in areas where the snow accumulation exceeded 2 feet. More than 88 percent of these winter sightings were made in areas with less than 18 inches of snow (Gilbert et al. 1970:18). By the end of January, almost all mule deer had moved to elevations less than 7600 feet (Gilbert et al. 1970:19).

In this area of the Rocky Mountains, mule deer count dropped after each winter of above-average precipitation and rose after each winter of below-average precipitation (Gilbert et al. 1970:21). Winter deer counts were shown to be inversely related to mid-to-late winter precipitation in north-central Colorado.

Robinette et al. (1952:290) discuss shifts in mule deer range and state,

> Mule deer in Utah normally frequent the lower mountain slopes at elevations varying between 5,000 and 7,500 feet during the wintering period from late November until mid-April or early May. Except for short periods following fresh snowfalls the south exposures in the foothills are bare during most winters. However, snow accumulates to depths of 2 feet or more on the north-facing slopes. Extended periods of freezing weather are uncommon.

The foraging area is reduced in size during the winter. Mule deer in northeastern Utah on the northern slopes of the Uinta Range utilize a combined winter home range equal to 280,000 acres, as opposed to 700,000 acres during the growing season (Richens 1967:655). Winter range in this area is covered with shrub vegetation including big sage brush, Utah juniper, pinyon pine, and mountain mahogany. The primary browse plant species include big sage brush and mountain mahogany (Richens 1967).

Richens (1967:664) provides a succinct discussion of mule deer winter foraging areas. Local deer numbers were determined by availability of food, snow depth and condition, temperature, wind, and the amount of protective cover. In cold, windy, or stormy weather deer were usually found in sheltered areas, particularly in heavy juniper stands. On cold, sunny days most deer occupied bare southern slopes where temperatures were highest and snow depth the least. Northern slopes were used heavily in the fall and spring but were abandoned during the winter when they were covered with deep, crusted snow.

Richens (1967: 664) also states that,

> During severe winters deer occupied only 60.5 percent of the area used during the normal winters, with upper range limits at 6,500-7,000 ft elevation.... Deer density varied from 81 to 135 deer per square mile on seven major concentration areas on the winter range....

Average deer density on both summer and winter ranges equalled 11.8 animals per square mile on 1,531 square miles of summer/winter range. The average winter range density for the Daggett herd equals 46 animals per square mile (1967: 664). In contrast, the winter deer density in northern Arizona equalled 70 deer per square mile (Richens 1967:664). These animals were dependent on mountain mahogany and sagebrush as key forage resources. The density of mule deer, then, varies throughout the annual cycle in the three plant communities present (Table 11).

ABORIGINAL LIFE ON THE COLORADO PLATEAU: REVISED VIEW

The specific interrelationships between snowfall and mule deer ecology used in this model can be modified and extended to cover elk and bighorn sheep as well (Figure 25). This explanatory model is applicable to a number of subareas of the American Southwest, including the Mogollon Highlands, the Colorado Plateau, and the southern Rocky Mountains in north-central New Mexico. It can also be modified and extended in order to account for prehistoric overwintering strategies in portions of the Northwestern Plains, the Great Basin, California, and northern Mexico. The general and realistic character of this model will enable archeologists to accommodate considerable variability in land use and mobility strategies, diet breadth, food storage, adoption and use of ceramic vessels, demographic shifts, and sedentism.

A significant portion of this model consists of a number of causal relationships that link winter precipitation to ungulate mobility, home range size, fertility, mortality, diet, and body composition. Many of these causal interrelationships are couched in terms of both Liebig's "law of the minimum" and Shelford's "aw of tolerance." In this regard, Bartholomew (1958, in Krebs 1978:20) states that, "The distribution of species will be controlled by that environmental factor for which the organism has the narrowest range of adaptability or control."

Adaptability and/or fitness is established by the minimum and maximum of the range of environmental factors such as temperature, water, energy, nutrients, toxins and/or antinutrients, and life space. In this study, we have seen that winter precipitation, specifically snowfall, exhibits variable effects on the physiology and behavior of ungulates. Excessive winter snowfall, low temperatures, and high winds in upland areas of the American Southwest impose severe limitations on ungulate mobility, availability of high quality forage, body fat reserves, thermoregulation, and

Table 11. Seasonal variation in mule deer densities per square kilometer during 1968-1969 (from Mierau and Schmidt 1981:12, Table 1).

Date	Entire Park	Mt. Brush	Sagebrush grass	Pinyon-juniper
June 22-Sept. 5 1968	17	30	20	5
Sept. 5-Dec. 21 1968	20	29	58	7
Apr. 26-Sept. 1, 1969	10	20	18	4
Sept. 1-Dec. 15 1969	18	29	22	9
Mean density	16.5	27	29.5	6.25

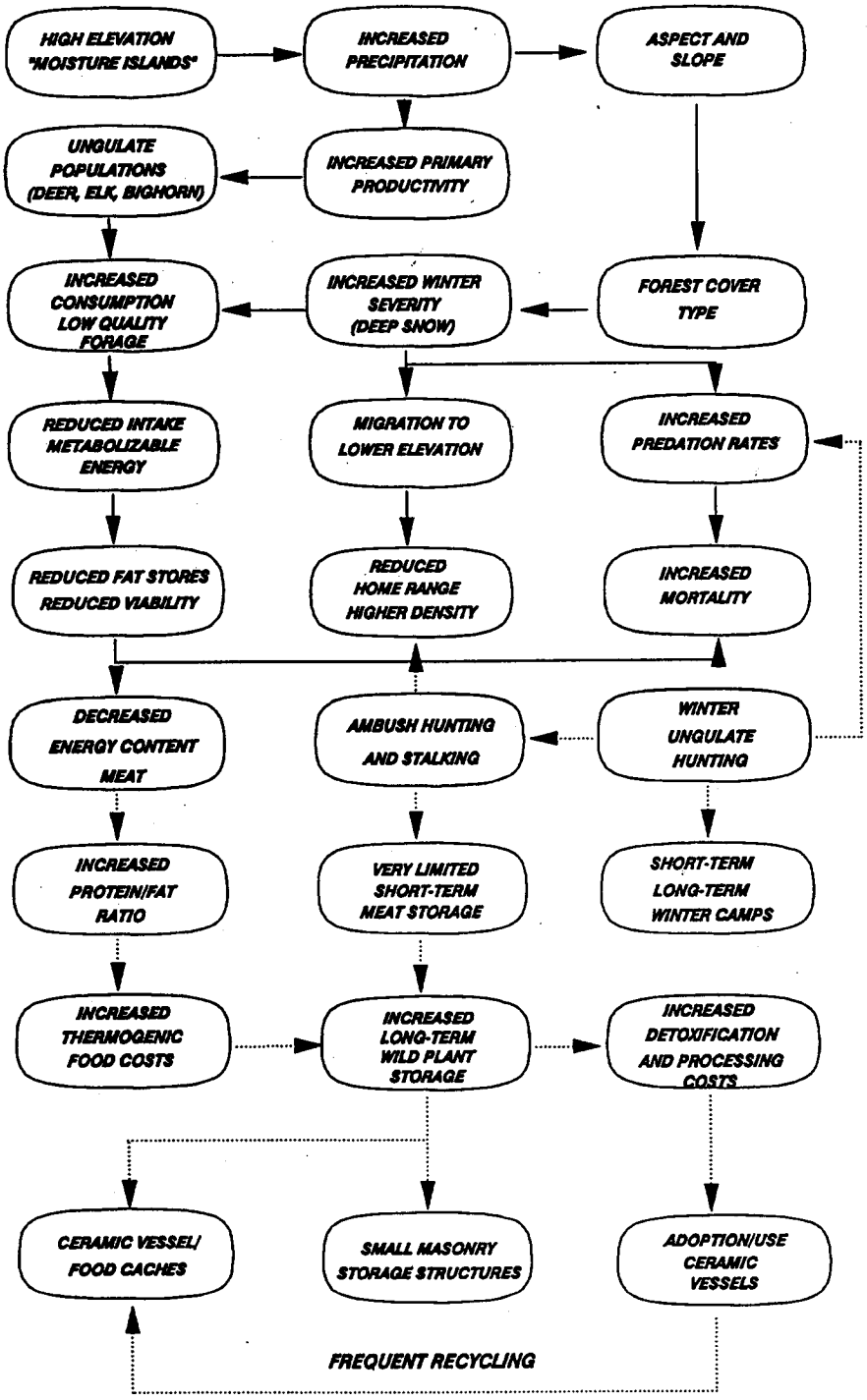


Figure 25. Aboriginal winter land use model.

offspring survival. At the other extreme, scant snowfall in these mountainous regions will delay the aggregation of ungulates and will delay their migration to winter ranges at lower elevations. Little snowfall may also mean that mule deer will continue to make use of relatively large home ranges during the winter. Limited snowfall may also adversely affect forage productivity and its nutritional composition and value during the next growing season. Inadequate quantity and quality of forage will retard the accumulation of body fat reserves. And, in turn, low fat reserves will reduce the capabilities of ungulates to endure more severe winters in the future.

As we have seen, high elevation questas and mesas like Mesa Verde and Black Mesa, plateaus such as the Kaiparowits and Kaibab areas, and mountain ranges including the La Sal, Abajo, and Chuska mountains represented relatively high biomass "islands" that supported sizable populations of mule deer, elk, and bighorn sheep. Isolated peninsulas, islands, and archipelagoes formed by mountain systems would have been preferred resource patches in the Desert Southwest. These moisture islands are produced by the dynamic interactions between topography and descending summer and winter air masses. Winter precipitation in the form of snow has very significant biometeorological implications for ungulate populations in these high elevation settings. As discussed earlier, winter snowfall and significant temperature declines trigger the fall migrations of ungulates, particularly mule deer, down from the higher elevation summer range to the overwintering areas that provide shelter, shallow snow, and more accessible forage. The fall migration coincides frequently with the first snow accumulation equal to 20-25 cm (8-10in). Most mule deer observed in the central Rockies were foraging in areas where snow accumulation was less than 45 cm (18 in).

Snow accumulation also restricts mule deer mobility. Home range size may collapse more than 60 percent and local densities increase more than four times. Such restricted winter home ranges may exhibit densities between 31 to 52 animals per square kilometer (81-135 per square mile). Winter reduction in home range size serves to concentrate ungulates. These aggregations can frequently be found on southern or southwestern exposures where snow accumulation is reduced. Increased aggregation and restriction of herds to southern slopes would have thus decreased search costs for aboriginal hunter-gatherers. Mule deer and/or bighorn sheep could have been stalked or ambushed in these microenvironmental areas. Game animals would be localized in very predictable settings if snowfall accumulation occurred within a tolerable temporal, spatial, and quantitative range. Heavy snowfalls, particularly in late winter or early spring can potentially decimate large portions of the resident herd.

Archeologists have generally underestimated the food resource potential of these large mammals. Grady's (1980) study of aboriginal adaptations and settlement locations in the Piceance Basin in west-central Colorado is a notable exception. Peak populations of mule deer, for example, in present-day Arizona, New Mexico, Colorado, and Utah exceed 1.34 million animals. Maximum harvests in this four state region equal approximately 366,000 animals per year (Connolly 1981). One mule deer provides an average energy yield of approximately 71,268 kcal; Three hundred sixty-six thousands mule deer could support almost 31,000 persons for 8 months of the year. Minimal populations and corresponding harvests equal 722,000 animals and 107,000 animals, respectively. These minimal harvests would support 9,046 persons for eight months per year. These gross population estimates do not include differential contributions of elk and bighorn sheep to aboriginal diet breadth. They also ignore the effects of overgrazing by domesticated livestock, fire and predator control, and contemporary development.

As mentioned, ungulates are assumed to be quite significant in prehistoric diets in this region because they exhibit very high return rates (kilocalories per unit handling time). This assumption is based on the optimal foraging study conducted by Simms (1984, 1987). From the standpoint of optimal foraging theory, we would expect to observe the addition of plants to hunter-gatherer diet as a response to the decreased availability of these high-return animal resources (O'Connell et al. 1982; Simms 1984, 1987). Plants exhibit considerable handling costs with respect to food processing, e.g., hulling, grinding, roasting, winnowing, baking, and boiling (Hawkes and O'Connell 1981). They may also represent considerable metabolic costs, due to secondary compounds—toxins and anti-nutrients—that include alkaloids, polyphenols, lectins, phytates, oxalates, proteinase inhibitors, nonprotein amino acids, and so forth (Bressani et al. 1982; Johns and Kubo 1988; Rosenthal and Jantzen 1979; Thomas et al. 1988; Walker 1982).

Physiologically, we find that both adult female and male mule deer undergo seasonal changes in body composition that specifically involve fat levels. For aboriginal hunter-gatherers, this means that the energy returns from the same unit weight of food declines markedly from summer and fall through the winter and spring (Figures 26 and 27). Ungulates not only exhibit significant declines in energy value, but the ratio of fat to lean carcass weight also declines. Increased protein-derived calories relative to fat-based calories is associated with increased diet-induced thermogenesis (DIT) or specific dynamic action (SDA). Consequently, the energetic costs for aboriginal hunter-gatherers overwintering in these higher elevation settings would have been compounded. The energy value of the food resource undergoes a marked reduction throughout the winter and spring. And, at the same time, a meat-based diet becomes more and more costly with respect to metabolic costs related to increased diet-induced thermogenesis (DIT) assimilation. This increased DIT cost may rise to approximately 30 percent of resting metabolic rate (RMR). Additional stress would also be imposed by cold temperatures and a corresponding increase in adaptive thermogenesis (AT) that involves physiological responses to cold stress in this case (see Woo, Daniels Rush, and Horton 1985).

Hunter-gatherers in the mountainous areas of the American Southwest most probably adopted an overwintering strategy that initially minimized their commitment to food storage. Ungulates are relatively well adapted to the rigors of winter throughout the western United States. Mule deer, elk, and bighorn sheep exhibit relatively high snow coping abilities related to morphology, physiology, and behavior. These animals have essentially solved the overwintering problem. Human populations, in turn, could have relied on stalking and ambush hunting throughout the winter. For example, the Ute of the southern Rocky Mountains hunted elk during the winter when deep snows forced the animals to yard or aggregate. Smith (1974:54, in Callaway et al. 1986:341) states, "Sometimes a small group of hunters on snowshoes would stalk elk, killing them when the elk tired, floundering in the snow." Aboriginal hunters used snowshoes in the mountains to reduce the ergonomic costs of walking in deep snow.

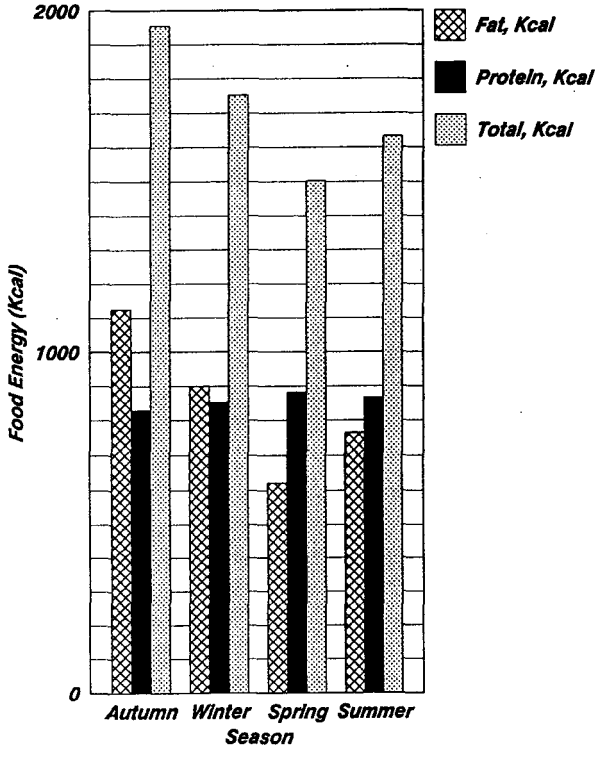


Figure 26. Seasonal change in food energy value, adult female mule deer carcass (1kg unit).

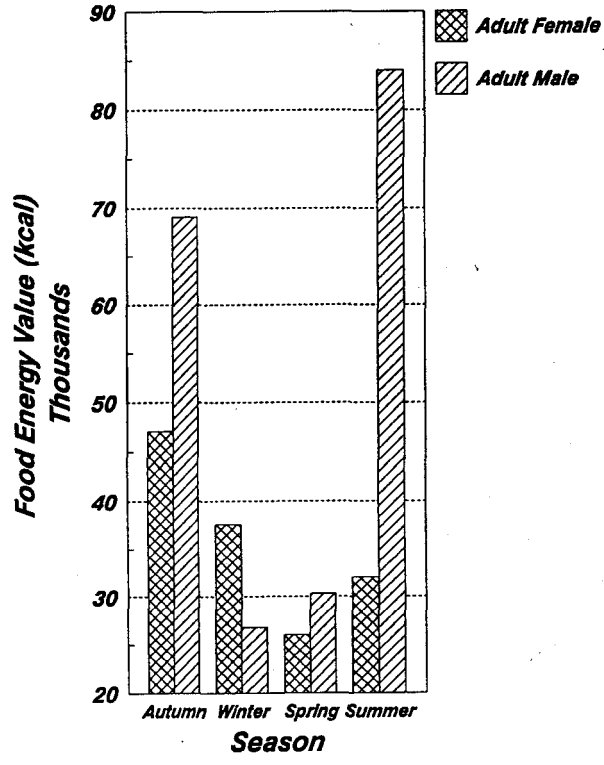


Figure 27. Food energy values for adult mule deer, seasonal changes based on carcass fat levels.

Circular snowshoes were made from bent stick frames covered with a rawhide lattice (see Callaway et al. 1986:342, Figure 3).

If aboriginal groups were to overwinter in mountainous areas where ungulates were compressed within small winter ranges by deep snows, we might expect to observe winter camps located within or above the pinyon-juniper zone. Callaway et al. (1986:343) state that,

> Although not equally abundant at all locations each year, the pinon groves were sufficiently scattered in Western Ute territory that some good crops of pinon nuts were found by nearly all Western Ute each year.... Fall gathering of pinon nuts was combined with deer hunting ... several families or even several bands might congregate and live mostly on pinon nuts and venison until deep snows forced a retreat to lower elevations. Pinon nut stores were revisited to carry supplies to camps at lower elevations (O. C. Stewart 1942:250).

Kelly and Fowler (1986:371) continue,

> Some chose to winter at high elevations, where snow was deep, fuel plentiful, and pine nut stores at hand. If pine nuts were not a staple, winter was passed at the foot of hills or in protected canyons, where snows were light, fuel abundant, caves handy as dwellings, and agave suitable. Water was not a problem; potholes were full and snow could be melted.

Winter residential sites probably included relatively short-term camps in areas where game was less constrained by winter snowfall and was therefore less predictable. Such camps might be similar to those described by John Wesley Powell in the late 1800s for the northern Ute in southern Utah and northern Arizona.

Powell (in Fowler and Fowler 1971:53) states,

> The camp ground is generally selected in the vicinity of a spring or stream of water and in a grove which furnishes partial protection from storms and affords fire-wood in abundance. There will be ten, twenty, thirty or forty families in the tribe, and each one will have its bivouac under the trees. In very cold weather the inner bark, [a kind of bast] of the cedar, which can easily be gathered in great quantities, will be placed on the outside of the bank of brush and piled in the limbs of the tree overhead so as to form a roof, an imperfect shelter from the rain. The site of the camp is never selected in low ground. They usually prefer a position on the sides of the hill or mountain, and they will carry water many hundred yards rather than camp in the low ground among the willows.

Winter residential sites may have been more permanent and/or subject to repetitive use throughout a number of years. These sites might look similar to those used by the Northern Paiute. The Northern Paiute overwintered in the mountains, where they occupied substantial semisubterranean, conical winter houses constructed of juniper and pinyon poles, brush, and earth. These dwellings ranged from 3 to 4.5 meters (10-15 feet) in diameter (Fowler and Liljeblad 1986:443).

In order to circumvent diminishing energy returns and increased diet-induced thermogenic costs, aboriginal hunter-gatherers could have adopted a limited plant resource storage strategy based on pinyon seeds, rice grass, wild rye, and other grass seeds. The bulk of these carbohydrate and oil-rich plant foods were generally obtained at lower elevations. Caches of these resources were most probably made close to productive patches of these resources during the harvest. Such caches could then be visited throughout the winter by logistical groups that resided at higher elevations.

With respect to the Southern Paiute, Kelly and Fowler (1986:371) state,

> For most, fall was a time of plenty and one of great mobility, with shuttling from high to low country and from one spot to another where collecting

and hunting were most favorable. Many moved to the mountains to cache pine nuts and hunt large game, returning to the valleys for rabbit drives. Highland seeds and berries were available, as was yucca fruit. All groups stored as much food as possible against the winter and recurrent spring famine.

Small isolated "granaries" that occur throughout much of southeastern Utah probably represent this form of overwintering strategy (Figure 3). Although no systematic study has been conducted, many of these features do not appear to be associated with long-term residential locations. No systematic study of these very interesting archeological features has been conducted. However, they have been observed throughout southeastern Utah in Canyonlands, Cedar Mesa, and Glen Canyon and elsewhere. They consist of two primary forms, including dry laid masonry and wet laid masonry structures. Both forms were constructed within relatively small, narrow overhangs or crevices. Gunnerson (1969:150) states, "The simplest construction consisted of walling up a niche of convenient size so that bedrock served as floor, ceiling, and all the walls but one." Such features generally have small sub-rectangular "doorways" or orifices that were fitted with well-shaped sandstone slabs (see Gunnerson 1969:Figure 22A). Free-standing structures in larger rockshelters possessed "doorways" in a side wall or in the roof (Gunnerson 1969:150). One might propose that the contents of dry laid masonry structures consisted either of foodstuffs sealed in other containers (i.e., ceramic vessels), or raw materials, implements, and facilities. The contents of these loosely constructed facilities could not be items threatened by insects or rodents. The wet laid, mud-plastered structures could have contained unprocessed foods in loose form or foodstuffs placed in vegetal fiber sacks, baskets, and/or gourd or ceramic vessels.

In addition, there are a number of isolated caches of ceramic vessels that have been located throughout the American Southwest and in southern California. Like the small masonry "granaries," these ceramic vessel caches frequently contained foodstuffs, i.e., carbohydrate- and oil-rich plant seeds and nuts. Frequently, such vessel caches contained processed food resources, including roasted pinyon nuts, mescal cakes, and grass seeds. These vessels were frequently hermetically sealed with lac from creosote bushes (see Osborn 1988). Both "granaries" and vessel caches could have been visited periodically by logistical groups from winter camps at higher elevations. These plant foods yield from 2,400 to 4,800 kilocalories per kilogram. Jones and Madsen (1989) have recently calculated that conical carrying baskets utilized historically in the Great Basin could transport a minimum of 21,672 kcal of wild rye or a maximum of 171,623 kcal of pinyon seeds (nuts). One basket load of pinyon seeds would then equal 2.4 mule deer (average carcass yield). The carbohydrate and oil-rich plant resources could then be consumed in limited quantities to offset the increased DIT costs of ungulates during the overwinter period. Plant storage based on grass seeds, mesquite beans, pinyon seeds ("nuts"), and so forth, was probably minimal, given the high processing and storage costs of these resources.

We might expect, however, that periods of climate change would impose significant constraints on this overwintering strategy. If winter snowfall was scant, then ungulate populations may not leave the higher elevation settings in the fall, nor would they aggregate in smaller winter home ranges and restricted winter feeding patches on southern exposures. This would increase the costs of hunting, and hunter-gatherers might shift to increased dependence on plant storage in the ensuing winters. Another scenario is that periods of severe winter conditions and deep snows might decimate ungulate populations and force increased dependence on stored plant resources for several years in the future. Continued stress imposed by extremely dry winters or cold, wet winters would require that aboriginal hunter-gatherers adopt a more specialized storage strategy based on well-monitored patches of energy-rich, highly storageable plant seeds, i.e., *Zea mays*.

Intermittent population increase on the northern Colorado Plateau during the Basketmaker and Pueblo periods is inferred from archeological remains on the basis of site sizes and density, the size of dwellings and their number, quantities of artifacts and food remains, and skeletal remains. Assumptions inherent in these methods are well recognized (e.g., Dean et al. 1985:542; Hassan 1981:63-92; Powell 1988:169-171), prompting Powell (1988) to assert that overestimation of population size is the rule. In any event, those methods currently available for making inferences about population density are believed to reveal general trends that allow areal comparison. The data showing variation in population increase throughout areas studied on the Colorado Plateau suggest a slow increase in population

well into the "pre-Formative"or Basketmaker period (Dean et al. 1985:542-544; Euler 1988).

Population density throughout the Archaic and until about A.D. 600 is considered to have been very low (Dean et al. 1985; Euler 1988). This period is broadly conceived as being characterized by a hunting and gathering way of life in which the degree of mobility fluctuated in response to spatial and temporal changes in resource availability. Procuring animal and wild plant food necessitated a highly flexible and opportunistic subsistence strategy in an environment characterized by a resource structure that was highly variable in space and time. Ethnographic and ethnohistorical analogy suggests that the adaptational system fluctuated from a warm-season, residentially mobile adaptation to a cold-season, residentially sedentary, logistically mobile adaptation. Small groups of perhaps 25-50 kin-related people are believed to have successfully practiced variations of this lifeway for several thousand years. No evidence exists, however of continuous occupation of southeastern Utah during this period. It has been suggested, based on climatic reconstructions, that intermittent, low-intensity occupation between 6000 and 1000 B.C. should be considered more likely than continuous occupation (Berry and Berry 1986). Environmental variables conditioning population density in arid environments have been examined by Birdsell (1953, 1978), Martin and Read (1981), Thomas (1972), and Vorkapich (1981).

These studies have explored the potential of annual precipitation to condition population density in Australia, the Kalahari, and the Great Basin. Both Birdsell (1978) and Vorkapich (1981) have acknowledged the need to include many additional environmental variables to account for population density variation. Nevertheless, it should be apparent that the density of hunter-gatherers is greater in areas where annual precipitation is higher, all other environmental factors held constant. In the study area, therefore, we should expect to see an archeological record attributed to the Archaic and "pre-Formative" periods resulting from a low population density.

Estimates of prehistoric population change are complicated by recognition that population densities are characterized by sharp localized fluctuations, when examined over long periods of time. Vulnerability to fluctuations in population size per unit area should be recognized throughout this period. Groups would be buffered only by their ability to switch from one dominant source of food to an alternative source (Ammerman 1975; Belovsky 1988). Although this period should be considered one of low population density in southeastern Utah, we do begin to see evidence (e.g., horticulture, storage) of the kind of adaptive responses that are expected when population density increases and when constraints on residential mobility are a condition of the sociophysical environment (cf. Hitchcock 1982).

Increase in population density beyond a threshold determined by the carrying capacity of the environment in a given home range dictates any number of adaptive responses. Fission of a kin based group can occur, whereby a portion of the group splits off to use an entirely different range or, more likely, one that overlaps that of the original group. The process is repeated when this subgroup reaches the threshold of the ability of the resource base to sustain them. At some point, however, the overlapping of home ranges stresses the regional resource base; and the socioeconomic systems begin to become increasingly dependent on domesticated plants and, at the same time, increasingly to employ a logistically mobile strategy (Binford 1983:210211). Migration as a response to population density—resource imbalance scenarios, called "the long-range mobility option" by Hunter-Anderson (1986:26), should also be considered in understanding the archeological record in southeastern Utah (see Berry 1982; Slatter 1979:71-119).

During the period between circa A.D. 700 and 1000 there is little evidence that aboriginal groups in southwestern Utah changed their fundamental economic organization; however, small homestead living arrangements of both semi-subterranean pithouses and surface domiciliary rooms were in use. Increased population growth circa A.D. 900-1150 and greater use of some canyon bottoms and deeper soil on mesa ridges for horticultural purposes is recognized. Aboriginal groups during this period exemplify logistically organized collectors practicing horticulture. These small village groups apparently established social networks that helped in buffering short-term food shortages and participated in food and non-food exchange. After circa A.D. 1150 people southeast of the study area appear to have been more concentrated in larger, multi-unit structures often constructed in large alcoves and situated around canyon headwaters and springs. Smaller hamlets of the period (A.D. 1150-1300) are located in high positions, either in canyons or on mesa tops. Many of these sites

suggest occupation by nuclear families or by small extended-kin groups.

It seems likely, given the information available, that many of the Puebloan groups employing an extensive storage strategy during the tenth through twelfth centuries found it necessary either to become more dispersed and residentially mobile after this time or to choose the "long-range mobility option" probably in response to the duration of arid conditions and concomitant changes in resource structure (cf. Berry 1982; Dean et al. 1985:546-547; Upham 1984).

The landscape of southeastern Utah was probably used simultaneously by groups in a foraging mode and by semi-sedentary collectors after the tenth century. This does not imply, however, that they were all successful at all times but only that a range of options was open to these groups in a sociophysical environment that varied considerably in its rate of change. Depending upon conditions of resource availability and competition for those resources, aboriginal groups may have found it necessary to remain flexible and opportunistic in terms of their position in the forager-collector continuum model. That is, sociophysical conditions might necessitate making relatively abrupt changes somewhere between employing a highly residentially mobile foraging strategy and a more logistically organized collector strategy, with horticulture as an important component of subsistence.

CONCLUSIONS

Long- and short-term transformations in aboriginal lifeways in the American Southwest have usually been explained through reference to increasing dependence on maize horticulture. As a result, higher elevation settings in this vast region have been delegated secondary importance in the development of regional/local land use strategies, due to climatic limits imposed on maize production. Almost all investigators have alluded to the potential or actual resources that such mountainous areas produce; yet prehistoric hunting has generally been assigned relatively minor dietary importance. Perhaps little significance has been ascribed to prehistoric and historic hunting, since many models of Archaic and Basketmaker adaptations are based on a Great Basin model. Historic hunting by the Hopi, Zuni, and Navajo has been described, but little effort has been given to assessing the relative contribution of animal resources to the historic diet.

This land use model is important, for it provides a conceptual framework that can be used to interpret the archeological record in the Canyonlands region of southeastern Utah. Archaeological remains on the Island-in-the-Sky suggest relatively short-term use. There is little evidence to suggest that locations on the Island-in-the-Sky were used for long-term residence. For example, the Gray's Pasture location (42SA16858) contained a number of ground stone implements, ceramic vessels, and a cycled olla that yielded evidence for the collection and processing of plants during the growing season. Faunal remains from this location also indicated that a range of mammals were hunted and perhaps processed adjacent to and within the site area. Marginal utility parts were discarded here, suggesting that logistical groups consumed low-utility parts and transported higher utility parts to other locations.

PROJECT DEFINITION AND FIELD METHODOLOGY

The Island-in-the-Sky road project was designed to improve the unpaved access road from Utah State Highway 313 to the Island-in-the-Sky District of Canyonlands National Park. The initial plan called for the rehabilitation of 42.5 kilometers (26.4 miles) of road. The project was divided into segments that bore the names of landmarks (see Figure 28). The first phase of the project focused on the roadway beginning 100 meters north of the Knoll, south to the Wye. From the Wye the road proceeds south to its southernmost extension at Grandview Point. The Murphy Point Spur Road leaves Grandview Point Road at a point approximately 3.7 kilometers (2.3 miles) south of the Wye. This spur road extends just over two kilometers to the southwest before it ends. Murphy Point continues as a narrowing peninsula of land a kilometer beyond the end of the roadway. The final road segment was defined as beginning at the Wye and continuing to the road's end at Upheaval Dome.

The roadbed was widened for the entire length of the project. In some cases, the roadbed was raised significantly (such as in Gray's Pasture). Road realignments took place in a few areas, such as between Alcove Spring and Whale Rock on the Upheaval Dome Road, at the Grandview Point terminus, and between the south end of Gray's Pasture and the Wye. Other development was associated with the improvement of parking and access to trails or overlooks or other visitor facilities. Archeological survey and evaluation outside of the road right-of-way was required at: (1) the relocation of the intersection of the Dead Horse Point State Park Road with the Island-in-the-Sky Road, (2) the relocation of the start of the Shafer Trail Road on the Island mesa, (3) the enlarged parking area and improved facilities at the Island Visitor Center, (4) the relocation of the Neck Spring Trail and the associated expanded parking at the Wayside Exhibit area above Shafer Trail, (5) the crescent-shaped parking area created for the Mesa Arch Trail, (6) the Buck Canyon Overlook development and the improvement of the picnic area on the Grandview Point Road, (7) the proposed creation of a large parking area at the end of the Murphy Point Spur Road, (8) the relocation of the intersection of the Green River Overlook Road with the Upheaval Dome Road, (9) the creation of a parking area for the Aztec Butte Trail, and (10) the development at the Upheaval Dome Picnic Area. Because of the proposed development of extensive trail systems and large parking areas, the field crew surveyed all of Murphy Point from the end of the spur road.

The fieldwork consisted of two basic activities, provenience plotting of surface cultural material and the excavation of test units in areas of differing surface densities. Recovery of information that allowed reconstruction of the spatial patterns of the surface debris was a focus of initial investigations.

In order to locate the surface cultural resources, the crew cordoned off a 50-meter corridor on either side of the proposed centerline of the improved road. Crew members then surveyed this corridor. Next, a mapping crew established stations from which to map in the surface artifacts and the test units. Test units were placed in areas of varying surface artifact density. Contiguous units were excavated in areas where a test unit revealed a cultural feature or an abundance of subsurface artifacts.

SUMMARIES OF FIELDWORK BY YEAR AND BY ROAD SEGMENT

The first field season of the Island road project began on August 2, 1983, and ended, due to inclement weather, on November 11. The crew varied in size from 9 to 11 people. Over 187 hectares along 20.46 kilometers of road were surveyed, surface artifact locations mapped, and test units excavated. Of this area, 7.44 kilometers lay on Bureau of Land Management (BLM) property. Five sites, 42GR910, 42GR911, 42GR912, 42GR913, and 42GR2025 were tested in this segment of the roadway. Sixty-seven one-meter-square units were excavated at these five sites. Forty-three other units were excavated on the BLM section. Survey ended in 1983 at 42SA8506, a point approximately 2.7 kilometers (1.7 miles) north of the Wye.

Field operations resumed on April 17, 1984, and ended on July 26. The crew of ten spent much of this field season on excavations at 42SA8506 and

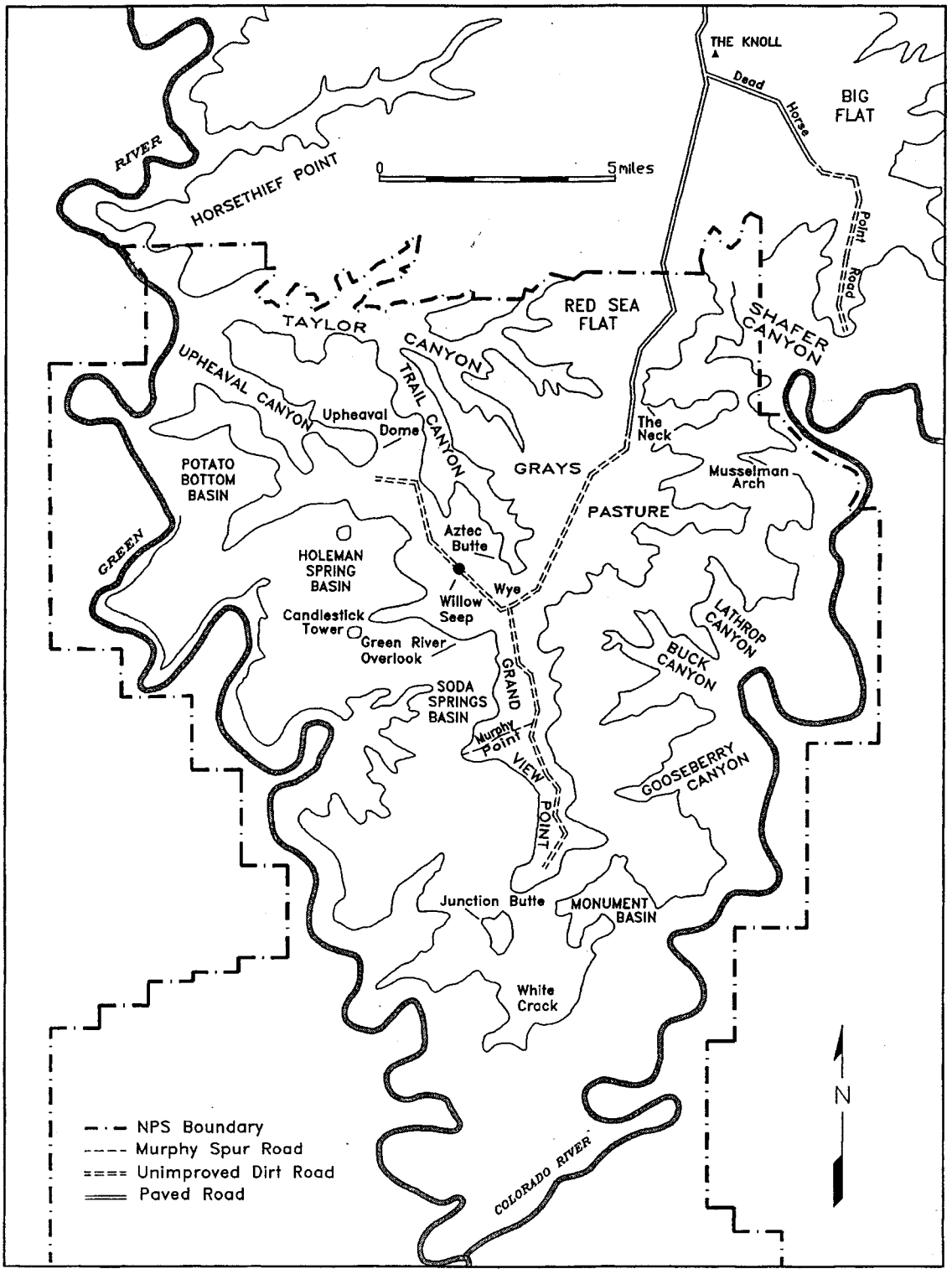


Figure 28. Geographical features located within the Island-in-the-Sky District.

42SA16858. An additional 56.55 hectares were surveyed along nearly six kilometers of road. The crew surveyed another 35.77 hectares at the proposed borrow for road fill located on BLM property.

The last field season began on May 6, 1985, and ended on October 31. The crew of eight surveyed the final 16.1 kilometers of road to Grandview Point, the Murphy Point Spur Road, and the rest of Murphy Point from the terminus of the spur road, and the Upheaval Dome Road. Over 217 hectares were surveyed. Table 12 records the number of mapping stations established, the number of surface artifacts plotted, and the number of square meters excavated by year. Table 13 summarizes the archeological work completed by road segment.

SURVEY METHODOLOGY

Of the 42.5 kilometers of road to be rehabilitated, 32.5 kilometers of the road lay in approximately a north-south direction. This alignment allowed the crew to work in two teams: an east team and a west team. All work followed the same sequence. First, blue engineering flags were placed 50 meters from the proposed centerline, perpendicular to its axis. These flags marked the lateral survey boundaries. Segments of 200 meters to 1,000 meters were surveyed each time. The 50-meter interval insured that coverage would be wide enough to take into account the widening of the road, the minor realignments in the road, equipment staging areas, truck turn-arounds during construction, digging of storage ponds for water used during construction, and

Table 12. Summary of archeological work by year.

Year	Mapping Station No.	Surface Artifacts	Excavated Area	Sites Tested and Evaluated
1983				
East	1-70E	5025 lithic 46 historic 28 ceramic	152 m^2	42GR910, 911, 912, 913, 2025
West	1-82W	14,089 lithic 16 historic 24 ceramic 3 beads 5 corn cobs	151 m^2	42SA421, 8502, 8506, 8513, 8514 8515, 16858
1984				
East	71-83E	2,221 lithic 41 historic	81 m^2	42SA3278, 8497, 8498, 8505, 8506, 8507, 16858
West	83-102W	16,569 lithic	31 m^2	
Borrow Area		26 lithic 3 ceramic	4 m^2	
1985				
East	84-140E	37,123 lithic 128 historic 23 ceramic	114 m^2	42SA415, 8495, 8496, 8499, 8500, 8501, 8503, 8509, 8510, 8511, 8512
West	103-152W	5,779 lithic 126 historic 3 ceramic 14 bone	138 m^2	

Table 13. Summary of archeological work by road segment.

Name of Segment	Distance	Area Surveyed (in hectares)	Surface Artifacts	Number of Test Units (1 x 1 m)
Knoll to the Wye	23.2 km 14.41 mi	212.07	19,990 lithic 62 historic 52 ceramic 5 corn cobs 3 beads 1 bone	374
Borrow Area		35.77	26 lithic 3 ceramic	4
Wye to Grandview Point	9.34 km 5.8 mi	91.96	22,583 lithic 82 historic	128
Murphy Spur	2.01 km 1.25 mi	70.6	32,292 lithic 133 historic 7 ceramic	47
Wye to Upheaval Dome	7.89 km 4.9 mi	86.4	6,231 lithic 80 historic 19 ceramic 14 bone	118
Total	42.4 km	496.8	81,122 lithic 357 historic 81 ceramic 3 beads 15 bone	671

any other ground-disturbing activities outside of the road bed. The Midwest Archeological Center did not receive plans showing where the above activities were to take place and consequently chose the 50-meter interval as one that would provide a margin for these activities. Where the proposed centerline no longer lay within the existing roadbed, the survey area expanded to include sections along the older roadbed. The use of heavy equipment to revegetate the old roadbed necessitated that the bed and its periphery also be examined.

In some areas, the survey perimeters had to be expanded beyond the 50-meter limit. In those areas where pull-offs were to be created, such as a Buck Canyon Overlook, Mesa Arch, and Aztec Butte, surveyors paralleled the proposed parking area limits. The proposed use of fill from an area on BLM property west of the Island-in-the-Sky Road, approximately four kilometers south of the intersection of this road with the Dead Horse Point Road, required that over 35 hectares be surveyed and tested in this area.

Five crew members, armed with orange engineering flags and spaced at 10-meter intervals, surveyed the demarcated area for artifacts. They flagged all cultural debris (Figure 29). In concentrations of artifacts, flags marked the center of clusters, with a 50-centimeter radius. All cultural debris within this circle was collected as one mapping location.

The survey team swept down one side of the road and returned on the opposite side. A mapping

team then located stations from which the artifact clusters could be plotted. From these stations, the instrument operator also mapped in the 1-m x 1-m test units. One mapping team operated on each side of the road. The mapping team stayed ahead of the excavators as much as possible. In areas of dense surface scatters, two or three mapping teams operated on the same side of the road.

In those areas where a test unit revealed subsurface concentrations of cultural materials, contiguous units were excavated. Almost all of the units excavated were 1 m x 1 m. They were excavated in five-centimeter levels by quadrant. The excavators passed all of the unit fill through 1/4-inch-mesh screen. Some 2-m x 2-m units were excavated. These units were also excavated in five-centimeter levels by quadrants within each one-meter quadrant. Sometimes the subsurface deposits warranted a block excavation. At the end of the 1983 field season and for most of the 1984 season, the crew worked on two block excavations at 42SA8506 and 42SA16858. Crew members excavated 47 sq m at 42SA8506 and 53 sq m at 42SA16858. Most of these units exceeded one meter in depth. Other block excavations were opened up on the east and west sides of the road at 42SA8502. Crew members excavated 75 sq m at this site. Multiple block excavations of a few units each were located at 42GR913, 42GR2025, and 42SA8512.

CATALOGING SYSTEM

The east and west sides of the road served as mutually exclusive systems. Mapping stations were numbered sequentially on each side of the road and their number was followed by an "E" (east) or "W" (west) for side. Test units were also numbered sequentially on each side of the road. Labels of "EX" and "WX" noted the side where the unit was placed. Because only 56 cultural features were identified on the project, the features were numbered sequentially without regard to side of the road. Since gridding the entire road corridor was impractical, mapping stations and test unit numbers had to be assigned in a sequential numbering system. This separate system for each side of the road allowed work to proceed at different speeds on each side,

Figure 29. Lithic scatter defined with survey pin flags near Murphy Trail.

without time lost coordinating unit or mapping station numbers. The east and west convention continued even on those segments of the road that did not preserve the north-to-south alignment. On the Murphy Point Spur Road that left the Grandview Point Road in a southwest direction, the north side of the road was the "west" and the south side the "east." On the Upheaval Dome Road that proceeded in a northwest direction from the Wye, the north side of the road was the "east," and the south side the "west."

Artifacts were numbered sequentially at the mapping station from which they were plotted, if they were surface artifacts, or within the test unit from which they were excavated. Surface artifacts had field catalog numbers preceded by an "FS" (field specimen) and followed by the mapping station number, a dash, the number of the artifact found at that station, and an "E" or "W" to indicate side of the road. For example, the fifth artifact mapped from Station 20 on the east side of the road would be labeled "FS20-5E" by the mapping crew. All artifacts collected within one mapping location with a 50-centimeter radius received the same number.

Test units were labeled, for example, "EX-5" for the fifth unit excavated on the east side of the road or "WX-7"for the seventh unit excavated on the west side of the road. All artifact bags from the test unit would have the "EX" or "WX"number recorded. The single catalog number recorded on the artifact would begin with a "T" for test unit, followed by the number of the test unit, a dash, the number of the artifact within the test unit, and an "E"or "W" for side of the road. Thus, the second artifact recovered from Excavation Unit 25 on the west side of the road would receive a field catalog number of "T25-2W" from the excavator. These catalog numbers served to organize the material in the field and in the laboratory. All artifacts recovered from the project are entered in the National Park Service Automated National Cataloging System (ANCS).

MAPPING PROCEDURES

Mapping of surface artifacts and excavation units was conducted using Ushikata pocket transits, a Lietz transit (10-C), a Nikon theodolite, and a Lietz(SDM3E) Total Station (electronic distance measuring device - EDM) during the course of fieldwork. Centerline pins and offset stakes left by Federal Highway Administration (FHWA) survey crews were used to tie archeological mapping stations into FHWA road plans. Archeologists shot in FHWA centerline pins, noting their station number whenever possible. These centerline points were recorded on FHWA plan maps at a scale of one inch equals 100 feet. Superimposed over these plans was the Utah state plane coordinate system based on blocks of 500 feet. The field supervisor was required to obtain exact coordinates of the central points established by the FHWA and used to tie centerline stations into the state coordinate system, and of the United States Geological Survey control points, for accurate mapping. All archeological work performed along the road corridor was consequently placed on the same coordinate system based on true north and measured in feet. East and west mapping stations were always tied into each other. The maximum error between the angle as measured from an east station to the west and backshot from the west station to the east is less than one minute of arc. All archeological mapping information used in this report should, therefore, be considered extremely accurate with reference to the state plane coordinate system. A full and detailed accounting of the process by which archeological information was coordinated with FHWA mapping and the Utah state plane system has been documented by the field supervisor and curated with records of the project at the Midwest Archeological Center, Lincoln, Nebraska.

FIELD RECORDING OF SPATIAL INFORMATION

Two Epson HX-20 computers were used for field entry of artifact provenience information. One computer was assigned to the recording of mapped information about surface artifactual material for each side (east-west) of the road corridor. Each computer was placed on a tripod-mounted plane table next to the mapping instrument in use (see Figure 30). Mapping information was then entered directly into the computer after each reading. Only information about station locations and benchmarks was entered by hand in transit books.

The data entry program, PTRANS, written by Robert Nickel and modified by Susan Vetter, recorded horizontal and vertical information, as well as the number and general kinds of artifactual materials being

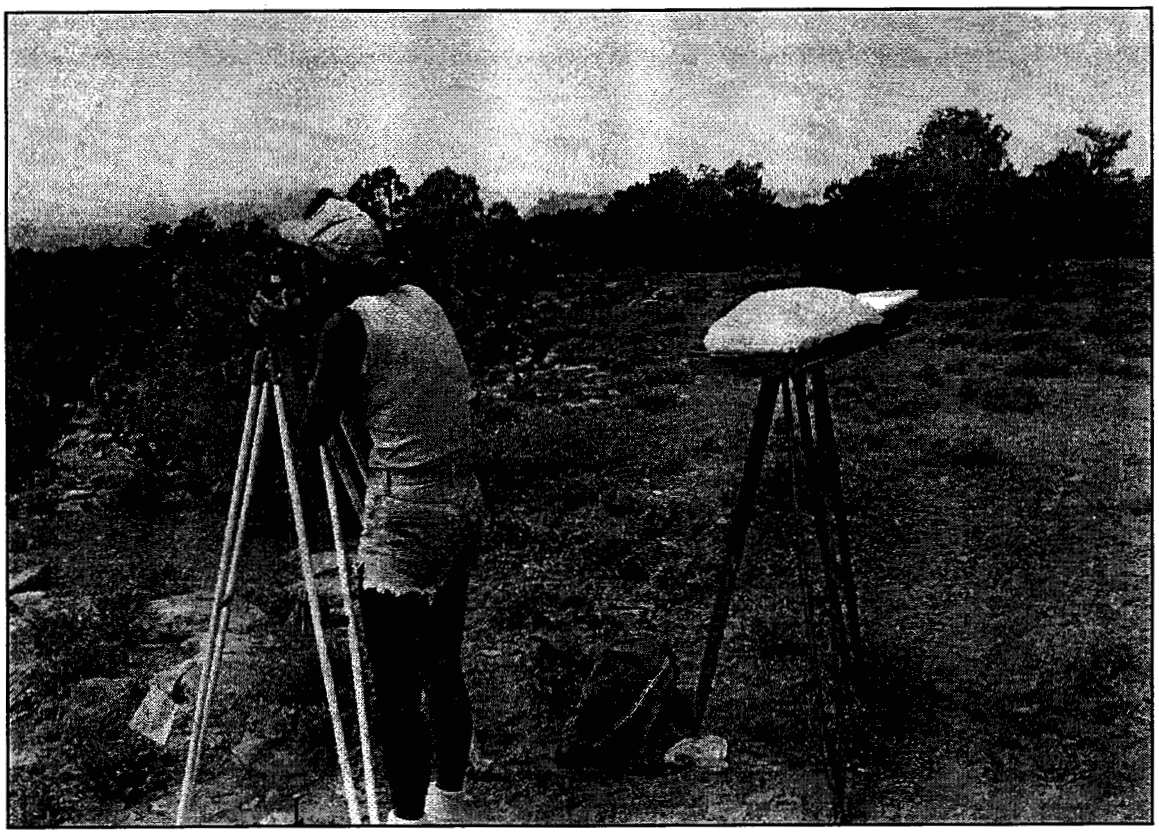


Figure 30. Field use of transit and Epson HX-20 computer at Station 114E, Murphy Point location (42SA8500).

recovered. This information was periodically (e.g., every five entries) transferred to a printout (adding machine tape) available with the Epson HX-20 structure. Microcassettes (MC-60) were also used to record this information via a serial interface with an internal microcassette recorder. One tape held a maximum of 830 mapping entries, or approximately 40 kilobytes of information. Hence, all mapping information was recorded both on paper and in tape recorded format. At the end of each day, the field supervisor pasted printouts into looseleaf notebooks to facilitate field and laboratory checking.

Data transfer from the Epson HX-20 to IBM personal computers for the analyses used in this report required extensive programming. An elaborate program (DUMP) developed by Susan Vetter permitted the transfer of fifty mapping records per session. This data transfer from microcassettes resulted in 448 files, occupying 890,810 bytes on the IBM-PC. Because of the format in which the records transferred, substantial programming and editing was required to allow subsequent data manipulation. A full accounting of programming steps for this process, developed and written by Susan Vetter, is curated with field and laboratory records of the project at the Midwest Archeological Center.

COMPUTER MAPPING

Isopleth and fishnet illustrations found in this report were produced using Surfer (version 4.0, Golden Software, Inc., 1989, Golden Colo.). Preparation of the spatial information for use with mapping packages required that special computer programs be written. Two programs written by S. Vetter, GROUP (BASICA) and DIVER (QuickBASIC 4.09), provide the ability to fluctuate the grid size across areal blocks to be analyzed and to subdivide an area into grids of different sizes. The program DIVER allows for calculation of diversity indices from data files, in addition to gridding the file into grids of any size. Grids from two to one hundred meters are used in this study. A full description of these and other programs used in this study, as well as a complete accounting of the process and limitations of these mapping programs has been authored by S. Vetter and is curated at the Midwest Archeological Center, Lincoln, Nebraska.

ARTIFACT RECOVERY AND SITE DESCRIPTIONS

Of the 35 sites reported by Hartley (1980), 27 of these would be impacted by the road construction. All 27 of these sites were relocated (Figure 31). Two of the sites, 42SA8499 and 42SA8501, were combined with 42SA8500 to create an extensive lithic scatter that covered most of Murphy Point, an area of almost 140 hectares. Two new sites were designated in 1983. 42GR2025 on Bureau of Land Management property at the Knoll was an extensive lithic scatter where over 1,600 surface lithics were collected. 42SA16858 in Gray's Pasture yielded few surface artifacts, but produced a wide variety of subsurface materials including over 1,000 ceramics, two nearly complete ceramic vessels, bone tools, ground stone, and cultural features.

Tables 14 and 15 display the summary of artifactual material recovered from the surface and subsurface at each of these 27 sites and from those areas not designated as sites. The totals for nonsite recovery reflect those mapping stations set up and test units excavated in areas between the 27 designated sites. The off-site approach to this project, wherein all surface artifacts are mapped and collected, quickly illustrates the limitations of the traditional site concept. As the patterns of artifact distribution reveal a continuous scatter of surface debris in varying densities, the boundaries of "sites" become more and more difficult to define and"isolated finds"less and less isolated.

In general, the cultural material recovered from the surface in nonsite areas was very sparse but nonetheless continuous in its distribution. However, pockets of dense lithic concentrations did occur. Many of these were seen around small exposures of the sandstone slickrock in Gray's Pasture. The consistent occurrence of surface lithic concentrations without any depth in the sand around these exposures may have indicated the postdepositional effect of wind deflation, or it may have reflected specialized prehistoric use of these pockets. Similarly, the extremely dense surface lithic scatters at 42SA3278, 42SA8502, and 42SA8512 occurred in areas with exposed patches of bedrock and little soil accumulation. The density of these deposits may also have been a product of postdepositional deflation or an indication of the desirability of these slickrock exposures for lithic reduction and perhaps, in the case of 42SA8502, for butchering.

LITHIC ARTIFACTS RECOVERED

Detailed analyses of the chipped stone tools, debitage, and ground stone are presented later in this report. Data tables for the chipped stone tools, subsurface debitage, and ground stone may be consulted in Appendices C and D. The following discussion is meant to offer a brief descriptive summary of the archeological data recovered during the project. A cursory examination of Tables 14 and 15 reveals that 42SA3278, 42SA8500, and 42SA8502 produced the greatest quantity of chipped stone from the surface. Of the chipped stone tools recovered at each site, 69 of the 70 tools at 42SA3278 were recovered from the surface, as were 159 of the 160 tools at 42SA8500 and 150 of the 232 tools at 42SA8502. The relatively small number of subsurface lithics recovered from 42SA3278 and 42SA8500 accentuates the surface nature of their distributions.

The diagnostic projectile points recovered at 42SA3278 were all found on the surface, and cluster into two distinct age categories. Three Desert Side-notched points and five points in the Cottonwood series represent the Late Prehistoric. Two Humboldt Concave Base points and one Pinto series point represent the Archaic. The diagnostics at 42SA8500 cover a wide range of ages as well. The seventeen projectile points at this site include Desert Side-notched, Cottonwood series, Rose Spring series, an Elko point, a Gatecliff Contracting Stem, a Sudden Side-notched, and a Northern Side-notched. Of the 80 projectile points recovered at 42SA8502, 71 of these are either Desert Side-notched or Cottonwood. Out of this total, 10 Desert Side-notched points and 19 Cottonwood points were excavated.

The remainder of the sites produced few diagnostic points. 42SA415 had two, representing the Archaic and the Late Prehistoric. 42SA421 had one Cottonwood point. Site 42SA913 produced five points, three from the subsurface. All represented the late Prehistoric period. Four of the five points at 42GR2025 were excavated. Three of these were Desert Side-notched or Cottonwood. 42SA8497 had two Rose Spring series points on the surface. 42SA8498 had a

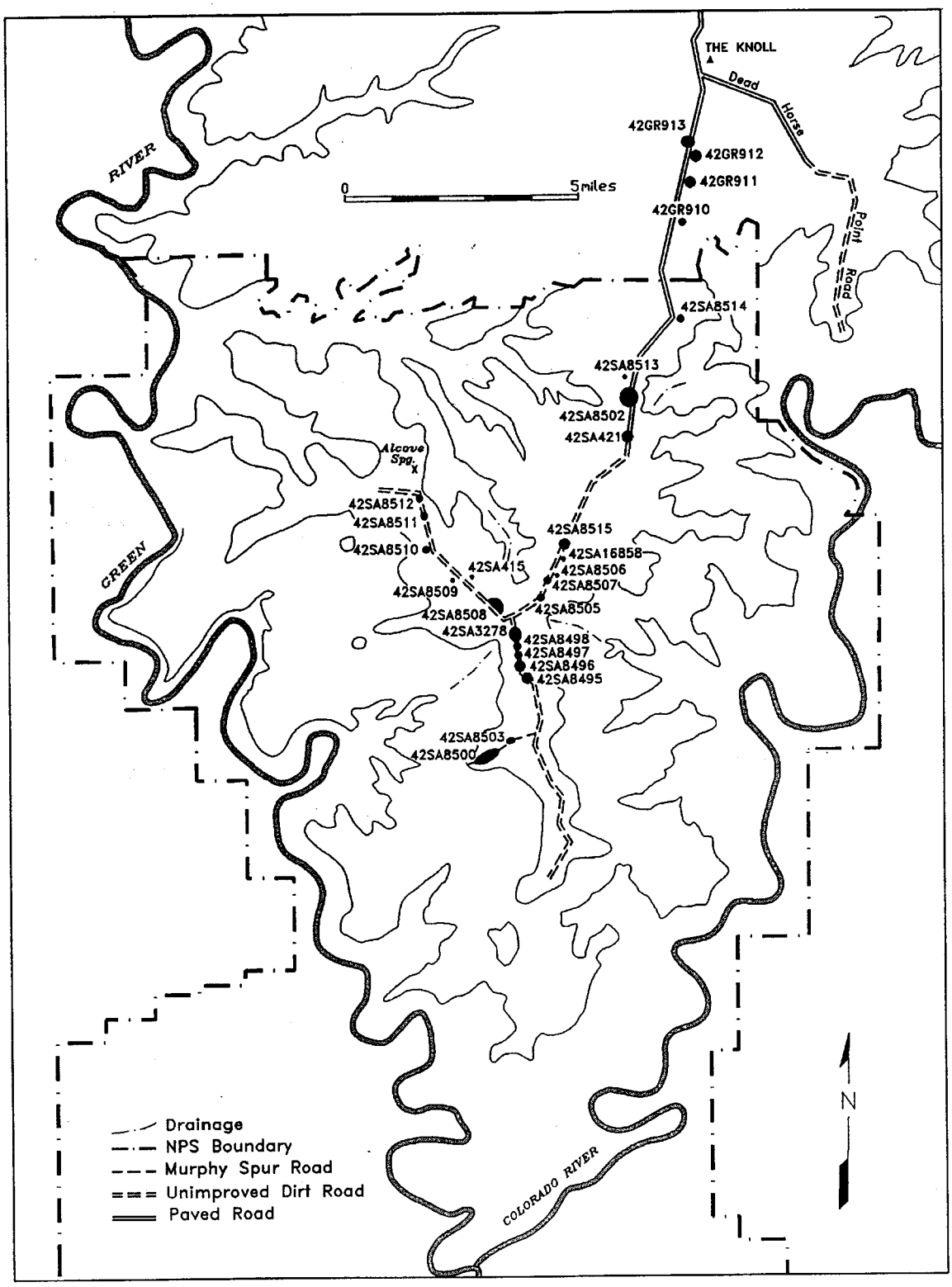


Figure 31. General location of archeological remains along the road corridor in the Isand-in-the-Sky District.

Table 14. Summary of flaked stone assemblages for Island-in-the-Sky sites.

Site	Mapping Points	Surface Lithics	Test Units	Subsurface Lithics
42GR910	7	7	2	2
42GR911	188	328	3	26
42GR912	148	183	4	8
42GR913	459	2490	43	2797
42GR2025	584	1656	19	213
42SA415	441	866	15	40
42SA421	177	588	5	68
42SA3278	1607	16240	22	165
42SA8495	72	139	12	20
42SA8496	986	3624	11	70
42SA8497	86	170	4	21
42SA8498	330	999	4	12
42SA8500	7041	32148	21	100
42SA8502	2511	11949	75	4055
42SA8503	109	143	22	289
42SA8505	182	676	3	3
42SA8506	29	28	47	309
42SA8507	49	157	2	20
42SA8508	851	2733	5	7
42SA8509	36	79	1	10
42SA8510	33	39	1	1
42SA8511	66	88	4	4
42SA8512	534	1803	30	210
42SA8513	209	438	13	40
42SA8514	7	4	4	0
42SA8515	22	43	7	27
42SA16858	27	29	53	290
Site Total	16791	77647	432	8807
Nonsite Total	1492	3088	249	391
Combined Total	18283	80735	681	9198

Desert Side-notched and a Humboldt Concave Base point on the surface. 42SA8503 produced a single Rose Spring point and 42SA8507 a single Elko series point from the surface. A Cottonwood, Rose Springs, and Humboldt Concave Base point composed the surface point assemblage at 42SA8508. 42SA8509 produced three Desert Side-notched points and two Cottonwood series points from its surface. Four Desert Side-notched points were excavated at 42SA8512. Seven other points found on the surface ranged from the Archaic Northern Side-notched to the Late Prehistoric Cottonwood. 42SA8513 produced three Late Prehistoric points. Finally, a Cottonwood and a Bull Creek point were excavated at 42SA16858.

42SA8502 and 42GR913 yielded many more pieces of debitage than the other sites. Figures 32 and 33 dramatically illustrate this dominance. At both sites, thinning flakes dominate the assemblage. 42SA8502 also has a high number of pressure flakes. 42SA8512 repeats this pattern on a smaller scale. Thinning flakes dominate the assemblage at 42GR913, 42GR2025, 42SA3278, 42SA8502, 42SA8503, and 42SA8512.

Table 15. Summary of archeological assemblages for Island-in-the-Sky sites.

Site	Chipped Stone Tools	Ceramics	Ground Stone	Historic Debris	Faunal Remains
42GR910	2	0	0	0	0
42GR911	0	0	0	2	0
42GR912	5	0	2	3	0
42GR913	51	0	11	12	94
42GR2025	21	0	24	2	1
42SA415	19	21	8	31	2
42SA421	9	1	1	0	1
42SA3278	70	0	4	9	0
42SA8495	1	0	0	3	0
42SA8496	33	0	1	2	0
42SA8497	7	0	1	0	0
42SA8498	15	0	0	0	0
42SA8500	160	2	5	60	3
42SA8502	232	55	12	11	282
42SA8503	3	301	0	52	24
42SA8505	5	0	1	0	0
42SA8506	9	969	19	1	12
42SA8507	1	0	0	0	0
42SA8508	30	1	1	10	0
42SA8509	10	0	0	2	2
42SA8510	4	0	1	5	0
42SA8511	0	0	0	2	0
42SA8512	65	1	5	24	278
42SA8513	15	0	5	0	1
42SA8514	0	0	1	5	0
42SA8515	0	0	1	3	0
42SA16858	15	1011	28	0	30
Site Total	782	2362	131	239	730
Nonsite Total	94	5	5	152	10
Combined Total	876	2367	136	391	740

Figures 34, 35 and 36 present these relationships graphically.

Pieces of ground stone collected from the surface and subsurface totaled 136. Sixty of these pieces were excavated at known sites. Data regarding ground stone implements is contained in Appendix D. Two manos and three metates were recovered from the surface outside of site areas. 42SA415 produced five manos and three metates. Four of the manos were biconvex in cross section. 42SA421 and 42SA8508 each had one mano and 42SA912 had two manos on the surface. Four manos and two metates were excavated at 42GR913. Of the 24 pieces of ground stone collected at 42GR2025, only five were excavated. Fifteen of the 24 pieces were metate fragments, most with an indeterminate form. 42SA8496, 42SA8497, 42SA8505, 42SA8510, 42SA8514, and 42SA8515 each had one metate fragment on the surface. Five pieces of ground stone were found on the surface of 42SA8500. Four metate fragments were excavated at 42SA8502. Eight pieces of ground stone were found on the surface. Four of the five pieces of ground stone found on the surface at 42SA8512 were manos. 42SA8513 also had five pieces of ground

stone. A mano and a metate were found subsurface at the site.

By far the most significant recovery of ground stone occurred at 42SA8506 and 42SA16858. These two sites received the most extensive excavation. 42SA8506 produced nineteen pieces of ground stone, including 12 excavated specimens. Three of the manos displayed a wedge-shaped cross section. Two had a plano-convex cross section. All 28 pieces of ground stone were found subsurface. The ground stone at this site contributed greatly to an understanding of subsistence activities at the site. The ground stone assemblage consisted of fourteen manos. Eight of the metates were washed with dilute hydrochloric acid to release any pollen grains trapped on their grinding surfaces.

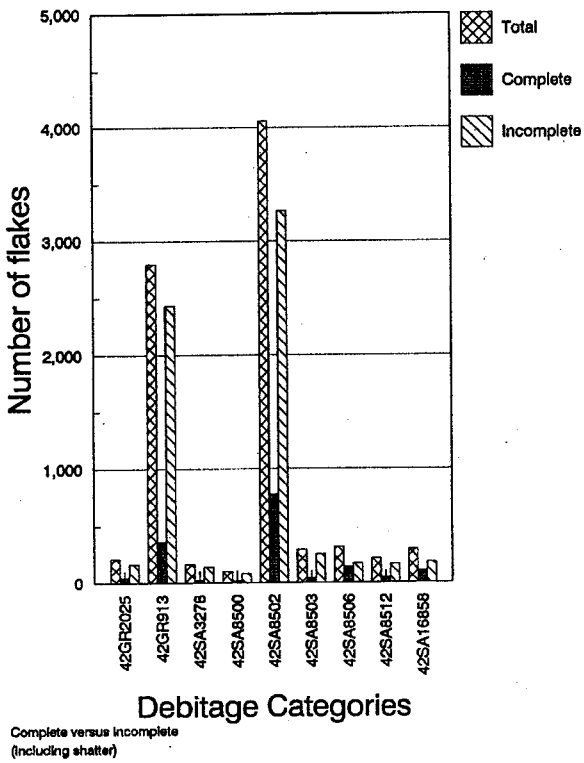


Figure 32. Summary of debitage for large site assemblages.

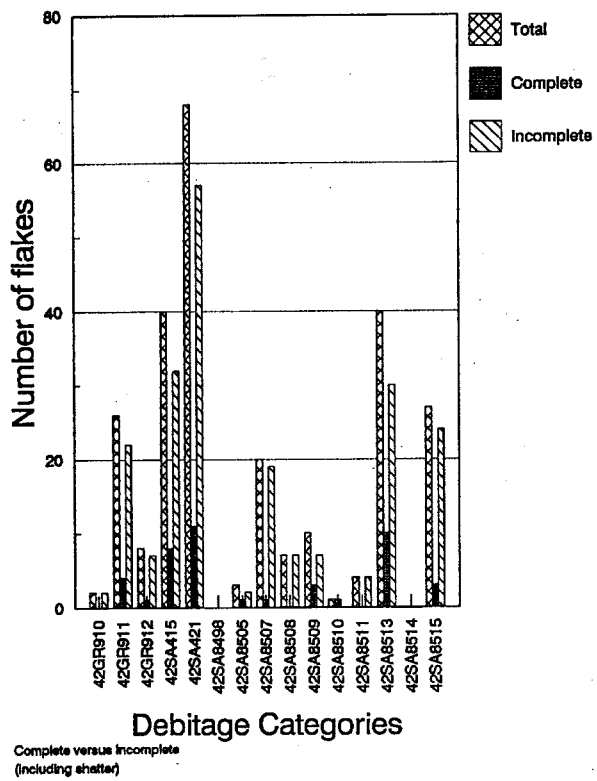


Figure 33. Summary of excavated debitage for small site assemblages.

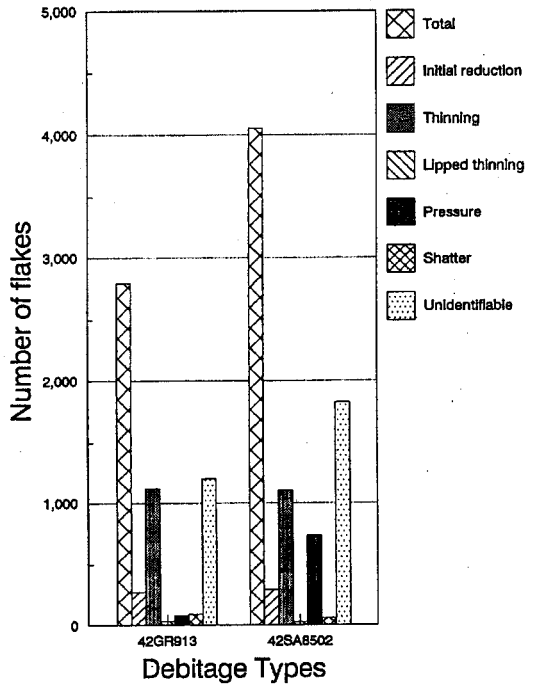


Figure 34. Debitage types by site: 42GR913 and 42SA8502.

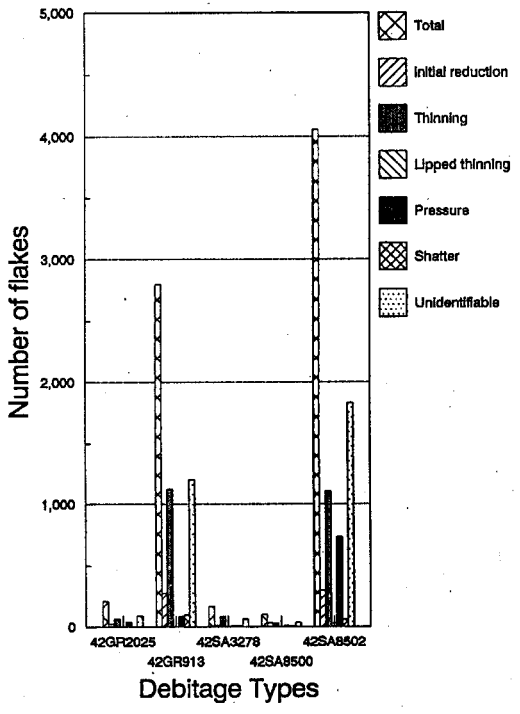


Figure 35. Debitage types by site: 42GR2025, 42SA3278, 42SA8500, and 42SA8502.

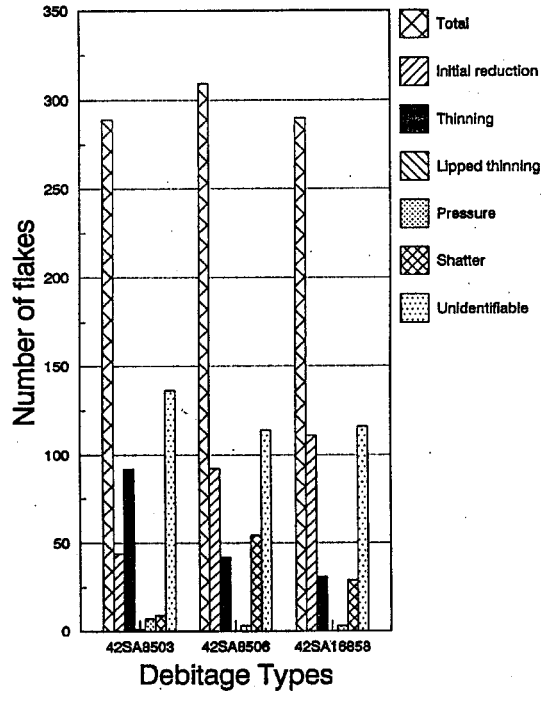


Figure 36. Debitage types for selected sites: 42SA8503, 42SA8506, and 42SA16858.

CERAMICS

The entire ceramic assemblage from the Island-in-the-Sky was examined by Dean Wilson. Wilson's ceramic codes and data are presented in Appendix E. Wilson's codes were converted into a numeric format. A computer program written by Vetter was then used to transform the ceramic file into a one record—one sherd format. This transformed data was then utilized to produce a number of graphical representations of the ceramic informtion. These graphs are used later in the specific discussion of ceramics.

Only five sherds, all of them on the surface, were found outside of the site areas. In the total assemblage of 2,367 sherds with 1,687 proveniences, only 76 were found on the surface. Sherds from 42SA8506 and 42SA16858 compose almost 84 percent of the total ceramic assemblage. Mesa Verde ceramic wares dominate the Island-in-the-Sky assemblage. Wilson identified 66 sherds with Kayenta affiliation, 50 with Paiute affiliation, and none with a Fremont affiliation.

FAUNAL REMAINS

The faunal assemblage contained 740 bone specimens. Eleven attributes were coded for each specimen. These codes and the data file are included in Appendix F. This faunal analysis utilized a quotient of species similarity. 42SA8502 and 42SA8512 produced the greatest number of faunal remains, 282 and 271, respectively. Artiodactyls dominate the faunal assemblage of both of these sites. In addition, both sites have a large number of lagomorph bone fragments. Interpretation of faunal remains at both sites is complicated by the fact that both site areas were at the top of livestock trails, along which cattle and sheep were driven from the Island top to below the mesa. Both sites have domestic sheep and cow remains. The shallow nature of the deposits at both sites causes the questions to be raised about the integrity of the subsurface deposits.

Sites 42SA8506 and 42SA16858 have much smaller faunal assemblages, 12 and 30 bones, respectively. No lagomorph remains were found at 42SA8506. Of the 23 sites with faunal remains, only one other site had no lagomorph remains. Many bone pieces (n=885) at 42SA8506 were unidentifiable. Similarly, 185 pieces of bone from 42SA16858 could not be identified. The large unidentifiable component at both of these sites may represent a processing location of some kind.

HISTORIC ARTIFACTS

The historic artifacts may be divided into two types. The first consists of the actual historic artifacts mapped and collected in the field. The second type of "artifact" was not collected. These artifacts are the historic features such as juniper corrals, rock cairns marking mining claims, holes drilled for seismic tests or stratigraphic tests, and so on. Of the 391 entries for historic material, one hundred and twelve of these entries actually record historic features that were not collected (Appendix G). In the case of historic dumps, if the dump contained a diagnostic artifact that could be used as a time marker, this artifact was collected. If the dump had no such artifact, it was simply mapped and coded as a historic dump.

The historic artifacts were examined and described by Ed Sudderth, Midwest Archeological Center, National Park Service, in Lincoln, Nebraska. The coding scheme was standardized for entry in a database file. This file contains 21 fields that record information regarding artifact type, provenience, and a comment field.

The historic artifact file begins with 192 records for artifacts not found on known sites. Thirty-three of these records refer to artifacts collected (28) and features mapped (5) at Dubinkey Well. Dubinkey Well is located off Highway 313 on Bureau of Land Management property several miles north of the Island-in-the-Sky. The archeological crew examined this area in 1984 when the Federal Highway Administration was searching for a water source for the construction activities on the Island road. Dubinkey Well was considered as a source.

The uncollected historic features preserve a record of the grazing, mining, and finally government regulation of the Island-in-the-Sky. Fence posts, juniper corrals, water troughs, and pipe all were left by the ranchers who grazed sheep and cattle on the Island before it became part of Canyonlands National Park in 1964. The rock cairns that served as mining claim markers, the seismic test holes, and the capped oil wells recall the hectic days of the 1950s when uranium miners

combed the area in search of a fortune and others began to exploit the oil and gas reserves of the Island mesa. Metal fence posts and rebar mark the beginning of government intervention in the 1960s, as public law attempted to preserve the area.

The collected artifacts reflect this same use. All are consistent with the record of historic activity in the area. Those who grazed livestock on the Island-in-the-Sky most often moved with their herds in the constant search for water. The sanitary cans, milk cans, and tobacco cans serve as reminders of this itinerant lifestyle. All of the artifacts date to the twentieth century. Those restricted to the early part of this century belonged to the cowboys who combed every canyon looking for water and good grazing for their livestock.

Historic artifacts from later in this century may have been left by either ranchers or miners. As miners scoured the area in search of uranium and oil deposits in the 1950s, the character of the historic artifact changed. Machine parts, seismic test wires, and glass bottle fragments all indicate the change in activities. Jeeps traversed the area, and with them came things that a saddlebag could not hold. The two 1953 license plates next to almost 100 meters of rock core removed from a nearby test hole dramatically emphasize this change.

Only sites 42GR910, 42SA421, 42SA8497, 42SA8498, 42SA8505, 42SA8507, 42SA8513, and 42SA16858 did not have subsurface historic components. In each case, the historic component almost always consisted of surface debris. However, 42GR913, 42SA8500, 42SA8503, and 42SA8512 did produce a few subsurface historic artifacts. Much of 42SA8503 consists of a corral with an associated concrete platform and associated debris. 42SA8515 also has a small corral on its surface. 42SA8502 contains the remains of what may have been a tent platform. These are the only sites with remains of historic structures.

SPATIAL DISTRIBUTION OF ARTIFACTS AT 42SA8506 AND 42SA16858

More time was devoted to the excavation of two sites, 42SA16858 and 42SA8506, than to any other. The extensive surface lithic scatters at 42SA8502 and 42SA8500 required considerable mapping time. 42SA8502 did have extensive subsurface deposits and a number of cultural features. However, no site had the diversity of artifacts, depth of deposits, and complex of cultural features that 42SA8506 and 42SA16858 revealed.

Figure 37 plots the artifact counts within the quadrants of each excavation unit at 42SA8506. A total of 46.5 square meters was excavated at 42SA8506, with a volume of 42 cubic meters. Seven cultural features were identified. Five of these received radiometric ages. The density peak in Figure 37 locates the center of the complex of features. As was mentioned above, a complete Kayenta corrugated vessel was excavated. It had been broken in situ. Figure 38 records the locations of all piece plotted ceramics at the site. The cultural affiliation, ware, and type for these ceramics is discussed later. Piece plotted lithics were not as abundant at the site. Figure 39 is a plot of their locations. This site also contained a disturbed human burial. Feature 39 intruded into this burial and removed the trunk of the body. Only the legs and lower arm bones were found in situ as Feature 34. The cluster of points in the center of Figure 40 records the position of Feature 34. Feature 33 was probably the remains of charred timbers that formed the superstructure of a pithouse at the site. Due to the sandy deposits within this site, it was difficult to delineate a house pit or floor. The site had been disturbed prehistorically by the excavation of Feature 39. The site may also have been disturbed historically by the road building activities of the Civilian Conservation Corps.

Excavation at 42SA16858 covered 53 square meters to remove 38 cubic meters of fill. Figure 41 is a plot of the artifact density at the site. All of the artifact counts including piece plotted and general level materials were placed at the center of each 50-centimeter quadrant in each excavation unit to produce this plot of total site density. As discussed above, 42SA16858 produced four complete ceramic vessels. The site also contained bone tools, several complete metates and manos, and three cultural features, two of which received radiometric ages. Figure 42 indicates the density of chipped stone material at the site. The quantity was summed to the center of each quadrant in each excavation unit in this plot. The high density area in the upper left region of the plot coincides with the location of the complex of ground stone at the site. The cultural "stratum" seemed to extend from 40 to 100 centimeters in depth. Feature 35, the complex of ground stone, and

the nearly complete corrugated pot all were found at 65 centimeters depth. Figure 43 presents the density of ceramics in this cultural deposit. The cluster in the center of the plot is Feature 40, where the large black-on-white olla was found. The macrofloral and pollen remains recovered from samples taken in this cultural deposit reveal that a wide range of plant processing activities took place on the site, including the grinding and storage of corn.

CULTURAL FEATURES

Fifty-six cultural features were identified. Of these, only Features 48 and 49 on the Upheaval Dome Road were not associated with a designated site. Both features lay adjacent to the road, were visible on the surface, and did not extend to greater than eighteen centimeters in depth. Their surface exposures and lack of depth may suggest that these were historic campfires. However, such a determination should be made cautiously in an area where a feature with surface exposure and shallow depth had an age of almost 3,000 years (42SA17597, Feature 1, on the White Rim).

All archeological features are discussed in detail in a later portion of this report. Table 16 presents the results of the radiocarbon assays for nineteen features along the road, for the single feature at 42SA17597 at White Crack on the White Rim, and for a sample from the Polley Secrest site (no site number) in Moab. All of the radiometric ages have been corrected to calibrated dates using the tables of Klein and others (1982). These calibrated dates have ranges with a 95-percent confidence interval. The continuity of the record from 1400 B.C. to historic times dispels the idea proposed for Cedar Mesa (Matson et al. 1983) that Anasazi occupations in the area in Basketmaker II, Basketmaker III, and Pueblo II/III times were each separated by a 200 year hiatus. Davis et al. (1989) and Reed (1990), in report of work conducted along Highway 313 on the way up to the Island-in-the-Sky, also did not find evidence for a hiatus in the area.

Three of the four Archaic dates (Features 46 and 47 at 42SA8500 and Feature 50 at 42SA415) came from slab-lined hearths that were visible at the surface. The Late Prehistoric dates at 42SA8502 are consistent with the abundance of Desert Side-notched and Cottonwood points, as well as with the few Paiute sherds found at that site. Similarly, the date from Feature 5 at 42GR2025 is consistent with the time horizon of the Desert Side-notched point excavated within the feature.

The dates from features at 42SA8506 and 42SA16858 are more problematic. All of the ceramics with definitive time horizons from the site date to Pueblo III occupations. Breternitz and others (1974:45-46) assign a date of A.D. 1200 to 1300 to this type. Other Pueblo III ceramics, such as the McElmo Black-on-white identified at 42SA16858, may date from A.D. 1075 (Breternitz, Rohn, and Morris 1974:41-43). These dates are at the upper limit of the radiocarbon dates obtained for 42SA8506 and 42SA16858. Given the Canyonlands area as a Mesa Verde outlier, this would not be expected to be the case. If anything, the dates from 42SA8506 and 42SA16858 associated with Pueblo III ceramics would be expected to be in the later half of the range rather than just touching on the earlier half. The consistent overlap in the dates does not suggest problems in the dating process itself. Certainly, the use of old wood in the Southwest is commonplace and may explain the discrepancy between the radiocarbon dates and the ceramic chronologies. The dating problem associated with the use of old wood or recycling is a perplexing one and merits further consideration.

In other respects, 42SA8506 and 42SA16858 fall into well-established patterns. The excavated Bull Creek projectile point at 42SA16858 (T145-15E) confirms the pattern noted by Holmer and Weder (1980) that Bull Creek points are almost always associated with Kayenta ceramics, but never with sites where Mesa Verde and Fremont ceramics are mixed. No Fremont ceramics were identified in the Island-in-the-Sky assemblage. The number of jar sherds at 42SA16858 and the presence of two ollas, one of which was set in a storage pit, reveal the importance of storage at the site. The location of both sites away from permanent water sources may indicate a spring and early summer occupation, when water may have been available in the slickrock pockets in Gray's Pasture. This time of occupation would coincide with the ripening of many spring grasses. 42SA16858 may have been a locus for plant processing. The abundance of ground stone at 42SA16858 and the pollen information recovered from it provide valuable clues into the subsistence practices of early inhabitants of the Island-in-the-Sky.

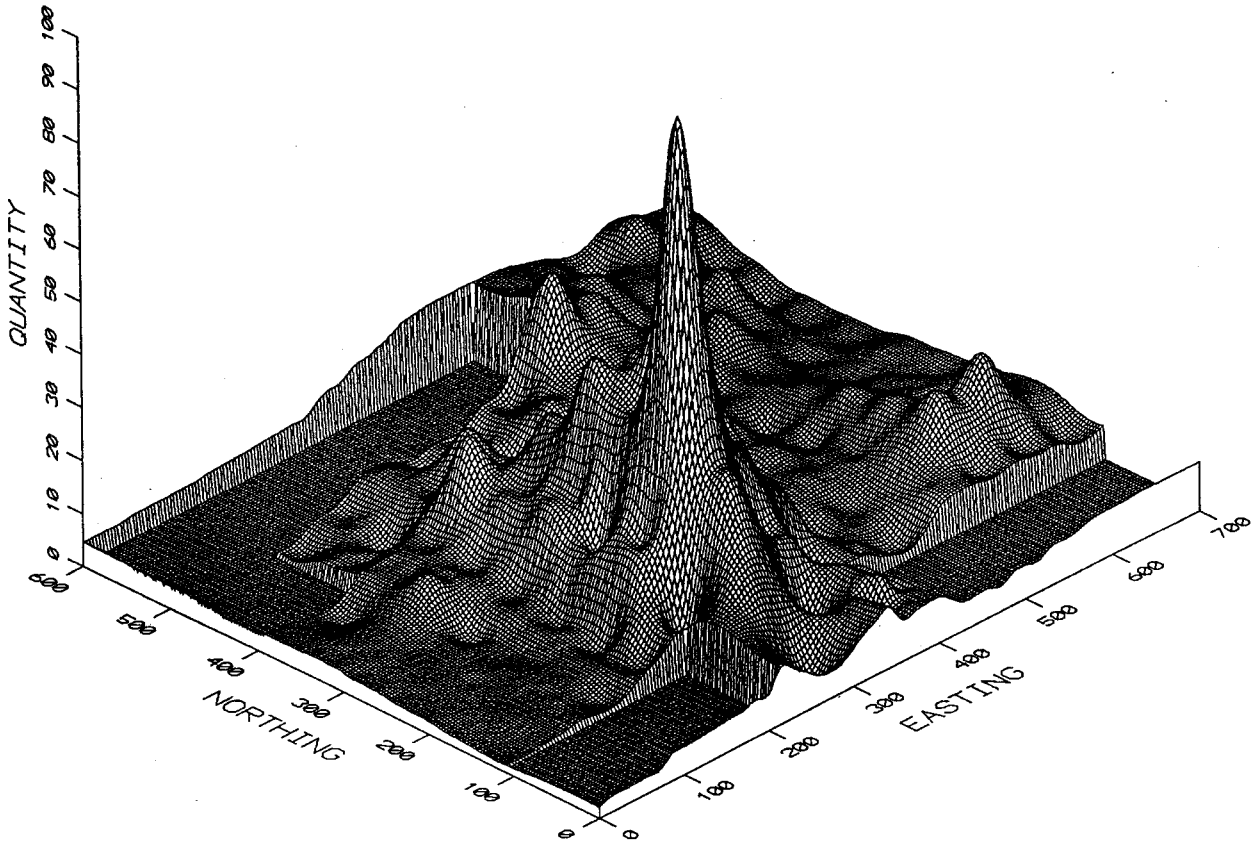


Figure 37. Fishnet density plots for excavated artifacts at the Dunes site (42SA8506).

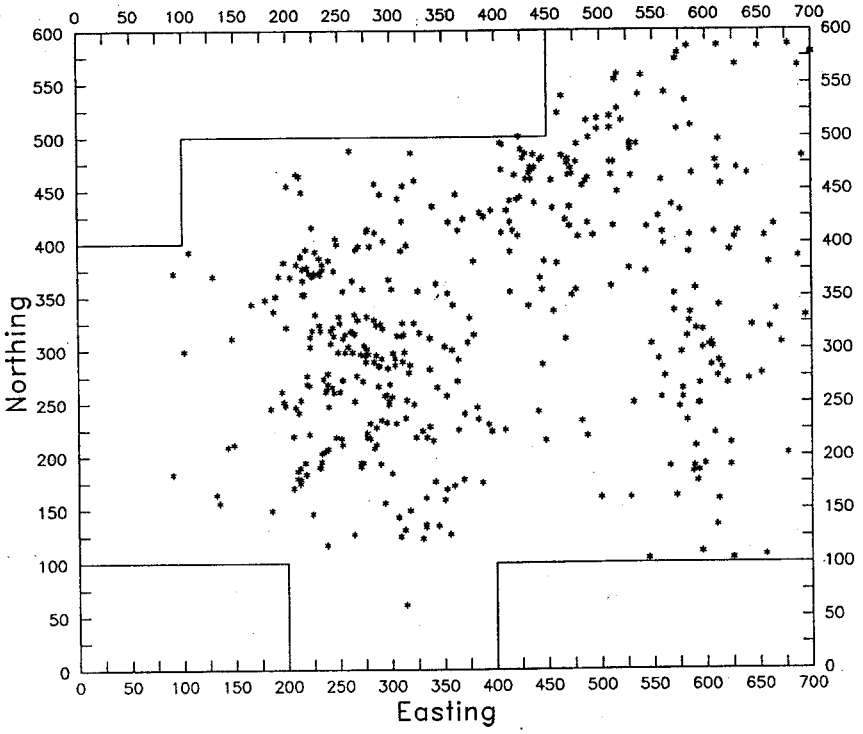


Figure 38. Piece plotted ceramics at the Dunes site (42SA8506).

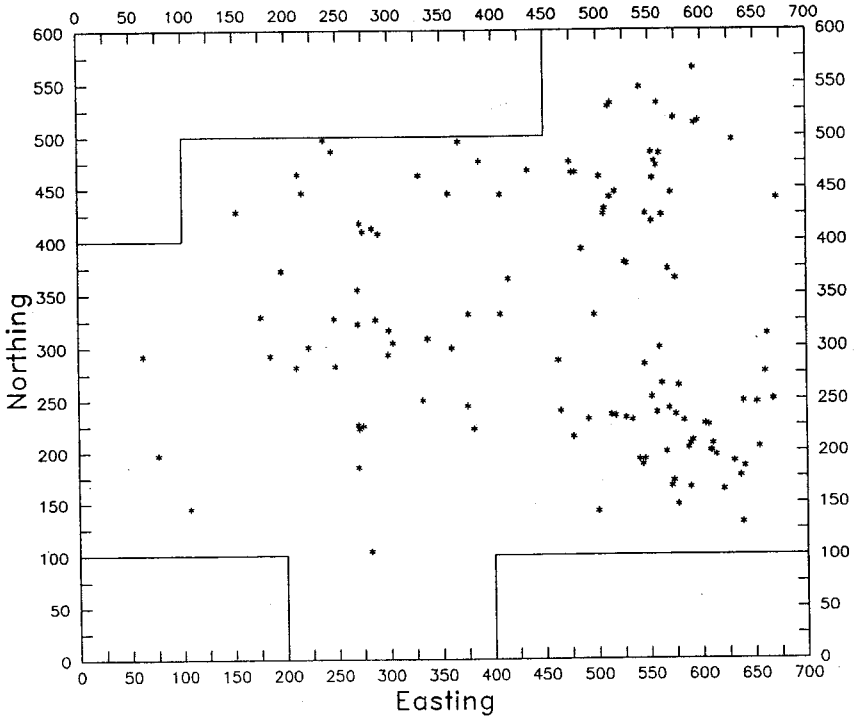


Figure 39. Piece ploted lithics at the Dunes site (42SA8506).

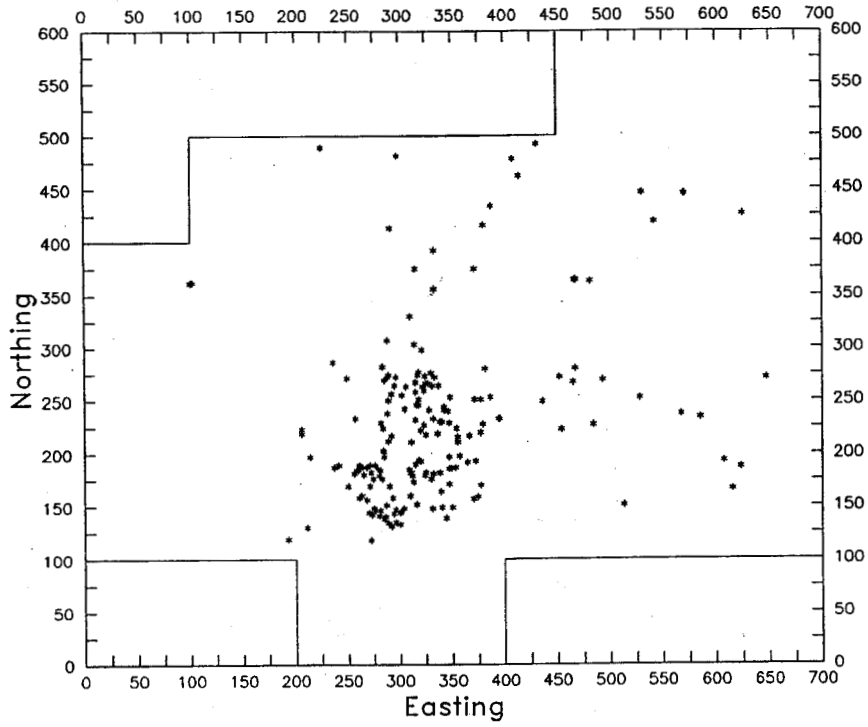


Figure 40. Piece plotted human and faunal remains at the Dunes site (42SA8506).

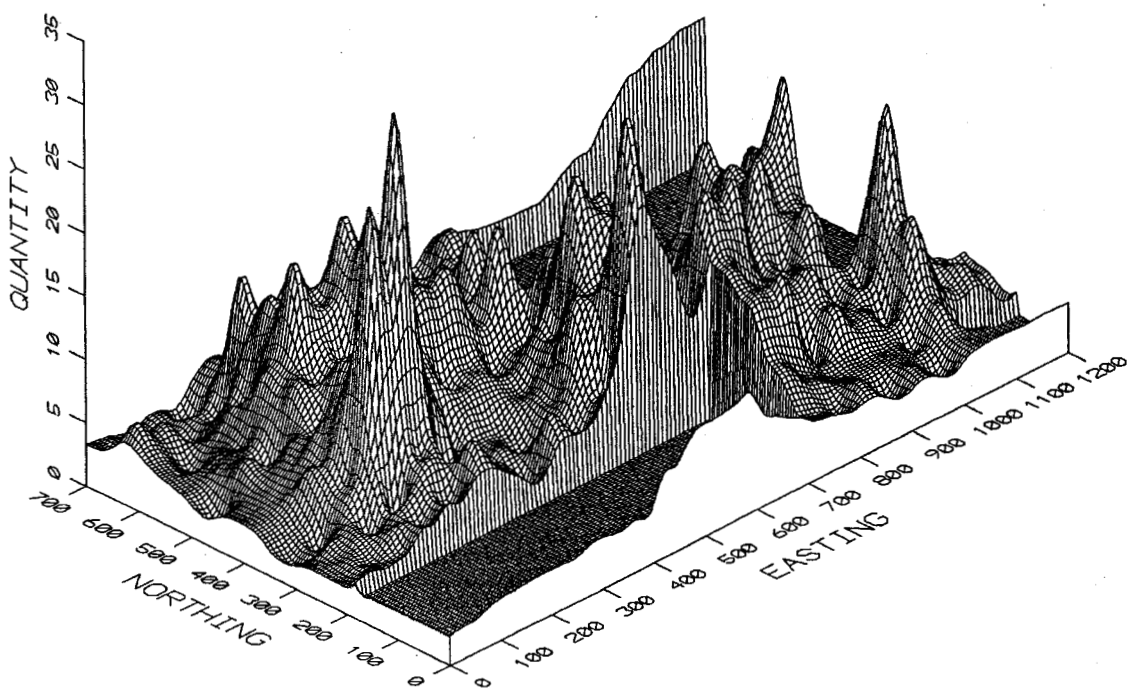


Figure 41. Fishnet density plot for excavated artifacts at Gray's Pasture (42SA16858).

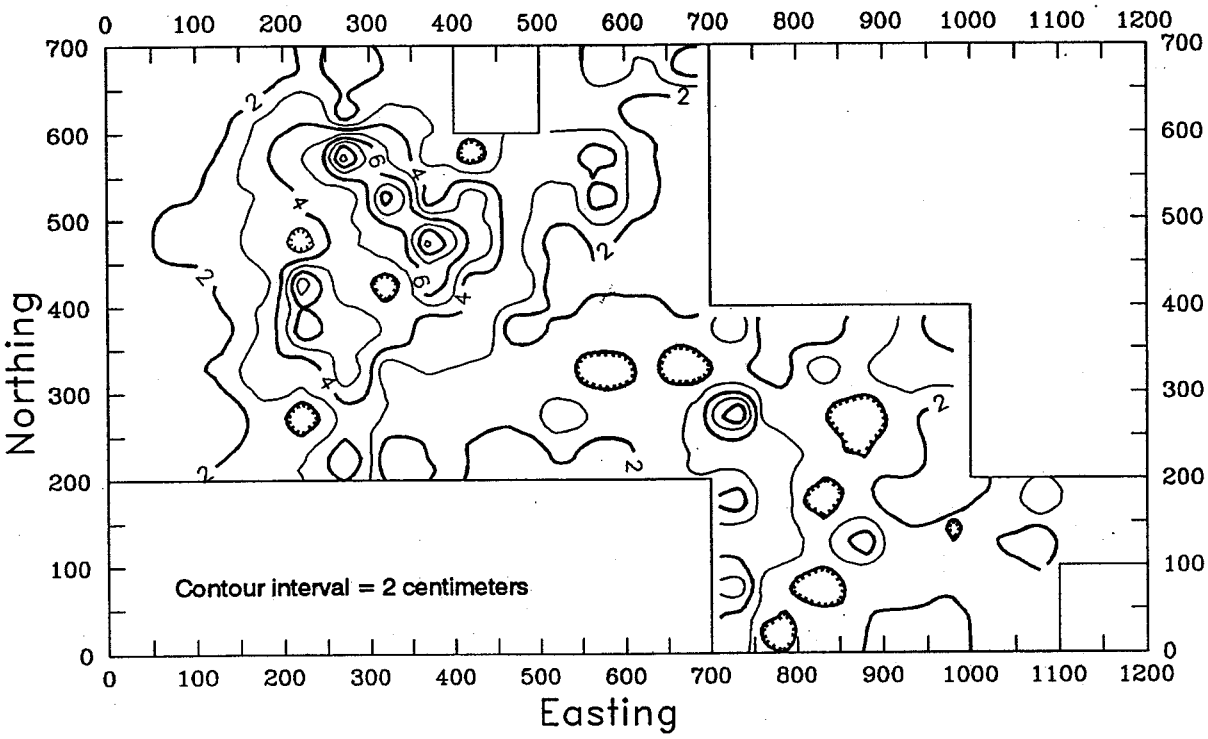


Figure 42. Density plot of chipped stone at 42SA16858.

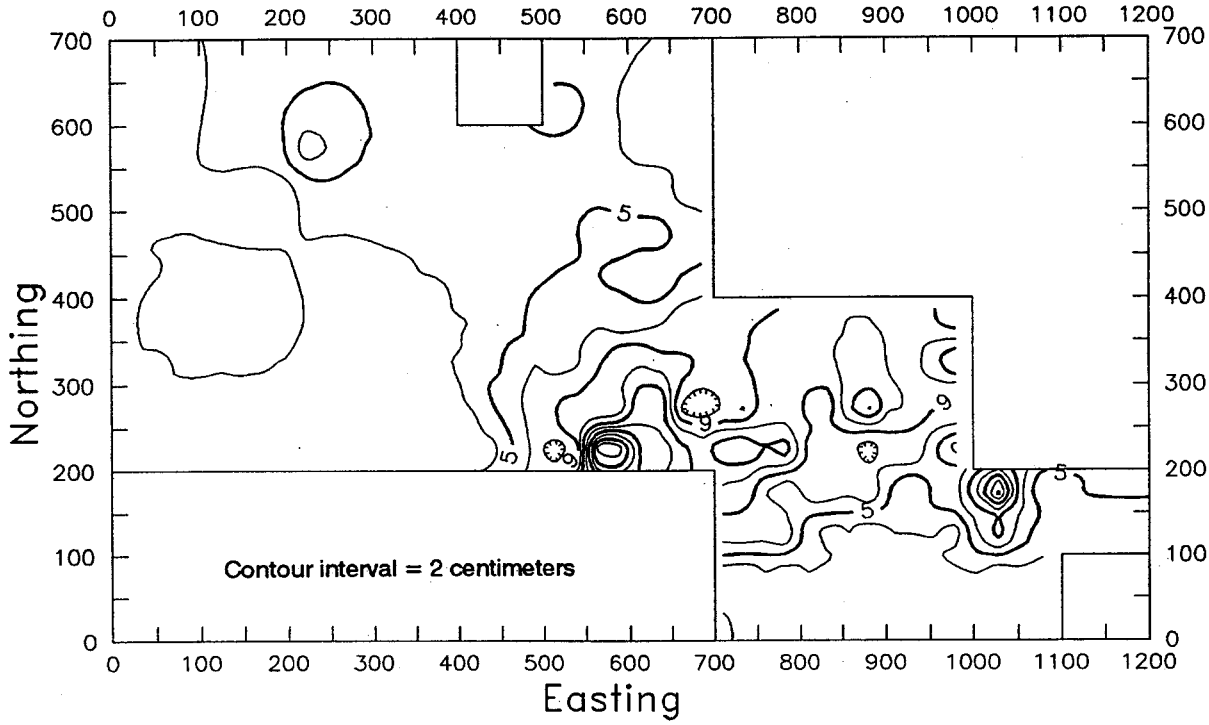


Figure 43. Density plot of ceramics between 40 and 100 cm at 42SA16858.

Table 16. Radiocarbon dates from the Island-in-the-Sky Project, Canyonlands National Park, Utah (based on wood charcoal).

Site	Laboratory No.	Radiocarbon Age	Calibrated Date[1]	Feature No.
1. White Crack (42SA17597)	Beta-24478	2990 ±70	1400-925 B.C.	EX-2
2. Polley Secrest (42SA—)	Beta-20470	640 ±60	A.D. 1255-1405	
3. Murphy (42SA8500)	Beta-20467	2740 ±60	1095-790 B.C.	47
4. Murphy (42SA8500)	Beta-20466	1730 ±70	A.D. 65-430	46
5. Murphy (42SA8500)	Beta-20465	310 ±70	A.D. 1425-1660	45
6. Alcove Spring (42SA8512)	Beta-20468	410 ±80	A.D. 1345-1650	56
7. Willow Seep (42SA415)	Beta-20469	2160 ±100	410 B.C.-A.D. 15	50
8. Dunes (Burial) (42SA8506)	Beta-20464	1240 ±70	A.D. 620-895	34
9. Dunes (42SA8506)	Beta-20461	940 ±70	A.D. 920-1230	38
10. Dunes (42SA8506)	Beta-20462	1290 ±80	A.D.585-900	36
11. Dunes (42SA8506)	Beta-20460	1050 ±50	A.D. 875-1055	39
12. Dunes (42SA8506)	Beta-9310	1000 ±50	A.D. 895-1195	33
13. Gray's Pasture (42SA16858)	Beta-20459	1210 ±80	A.D. 610-1020	35
14. Gray's Pasture (42SA16858)	Beta-27646	1335 ±65	A.D. 690-795	41
15. Neck (42SA8502)	Beta-9312	630 ±80	A.D. 1235-1415	7
16. Neck (42SA8502)	Beta-9311	120 ±50	A.D. 1655-1950	14
17. Neck (42SA8502)	Beta-9309	330 ±60	A.D. 1425-1655	26
18. Neck (42SA8502)	Beta-9308	270 ±50	A.D. 1485-1795	
19. Neck (42SA8502)	Beta-9307	320 ±50	A.D. 1425-1655	6
20. Knoll (42GR2052)	Beta-9306	990 ±60	A.D. 900-1205	5

[1]Klein et al. 1982 – Dates calibrated with 95% degree of confidence.

[2] ETH-4585

ARCHEOLOGICAL FEATURES

INTRODUCTION

Archeological excavations in the Island-in-the-Sky District revealed 48 features. These features consist of a variety of charcoal and ash stains, bounded and unbounded hearths, and relatively small pits. The majority of these archeological features can be thought of as nonportable facilities, as defined by Wagner (1960). Facilities "... serve to prevent motion or energy transfers—that is, fish weirs, nets, pottery" (Binford 1968:272). It is believed that many of these facilities were associated with food processing and storage. Burned and unburned faunal remains, macrobotanical material, and pollen were recovered from the soil matrix within these facilities. Detailed analyses of animal bone, charred plants, and pollen are presented in the section of this report that deals with ecofactual material. A detailed description of the excavated features is provided in the following discussion.

FEATURE INVENTORY AND GENERAL DESCRIPTION

An inventory of the excavated features and a codesheet for the database are presented in Tables 17 and 18, respectively. A summary of feature types, shapes, and contents is provided in Table 17. Given this summary, we find that charcoal and ash stains are the most predominant feature type. Irregular plan views are the most characteristic outline; more than one-third of all features exhibited basin cross sections. More than 68 percent of all features contained artifacts, and the most frequently occurring artifact was debitage. Ceramic vessel fragments were recovered from more than 14 percent of the features.

FEATURE DESCRIPTIONS

Feature 1, 42GR913

Feature 1 was a shallow, basin-shaped charcoal stain located in Excavation Units 15W and 18W. The stain had an oval shape when exposed at 28 cm bs. It measured 18 cm from north to south and 39 cm from east to west. Its fill consisted of a fine silty sand with scattered charcoal flecking, measuring 4 to 7 cm thick. The majority of the stain lay in Unit 15W. The section of the stain located in Unit 18W had a blocklike cross section, and though documented as part of Feature 1, it had an unclear association with the rest of the feature. Part of this ambiguity was created by the presence of root activity in the feature. No artifacts were recovered from the feature. Charcoal and soil samples were collected.

Feature 2, 42GR913

Feature 2, an irregularly shaped charcoal stain, was located in close proximity of the northeastern edge of Feature 1 in Unit 18W. It measured 26 cm from north to south and 12 cm from east to west. The stain was exposed at 22 cm bs and had fill from 7 to 12 cm thick. The stain was similar to Feature 1, though exhibiting a denser accumulation of charcoal. In planimetric view, the stain appears to extend to the north and west, however, it was not visible in those adjacent units, 15W and 22W. Root disturbance was apparent in the feature. No artifacts were recovered. Charcoal and soil samples were collected.

Feature 3, 42GR913

Feature 3, located immediately to the west of Feature 2 in Units 18W and 22W, was another irregularly shaped charcoal stain. It was separated from Feature 2 by a diagonal corridor of sterile fill, possibly a rodent burrow. Feature 3 measured 26 cm from north to south and 20 cm from east to west. It was exposed at 22 cm bs and contained fill 6 to 7 cm thick. The presence of root activity obscured some of the feature cross section. No artifacts were recovered. Charcoal and bulk soil were collected.

Feature 4, 42GR913

Feature 4 was a semicircular rock alignment located in Unit 14W and 14N at 42GR913. The configuration was visible at the surface and covered an area extending 180 cm from northwest to southeast.

Table 17. Summary of excavated features for the Island-in-the-Sky District.

Site	Feature Number	Excavation Units	Dimensions	Depth (in cm below datum)
42GR913*	1	WX-15,18	18 cm N-S 33 cm E-W	28-32
42GR913	2	WX-18	26 cm N-S 12 cm E-W	22-28
42GR913	3	WX-18,22	17 cm N-S	22-29
42GR913	4	WX-14, 14N, 14N ext.	120 cm N-S 60 cm E-W	0-50
42GR2025*	5	WX-54	98 cm N-S 76 cm E-W	0-10
42SA8502*	6	EX-54	100 cm N-S 110 cm E-W	0-15
42SA8502*	7	EX-55	100 cm N-S 60 cm E-W	0-10
42SA8502	8	EX-56	90 cm diameter	0-8
42SA8502	9	EX-57	70 cm N-S 49 cm E-W	0-10
42SA8502	10	WX-91	60 cm N-S 57 cm E-W	0-15
42SA8502	11	EX-55,58, 61	56 cm N-S 33 cm E-W	10-19
42SA8502	12	EX-55,60, 62	36 cm N-S 29 cm E-W	2-5
42SA8502	13	EX-55	23 cm diameter	1-7 (?)
42SA8502*	14	EX-58,59, 63,64	40 cm diameter	2-13
42SA8502	15	WX-92	Non-cultural	
42SA8502	16	EX-63	23 cm N-S 18 cm E-W	14-16
42SA8502	17	EX-56,66	65 cm N-S 75 cm E-W	5-10
42SA8502	18	EX-55	10 cm diameter	0-5
42SA8502	19	EX-55	8 cm diameter	1-8
42SA8502	20	EX-66,67,68	Non-cultural	

Table 17. Continued.

Site	Feature Number	Excavation Units	Dimensions	Depth (in cm below datum)
42SA8502	21	EX-55	Non-cultural	
42SA8502	22	EX-55	20 cm diameter	10-15 (?)
42SA8502	23	EX-58,63	78 cm N-S 55 cm E-W	14-23
42SA8502	24	EX-55	Non-cultural	
42SA8502	25	EX-55	11 cm diameter	10-16 (?)
42SA8502*	26	WX-93,102, 103	102 cm N-S 100 cm E-W	40-45
42SA8502	27	EX-64,65	Non-cultural	
42SA8502	28	WX-97,98	66 cm N-S 63 cm E-W	43-45
42SA8502	29	EX-63	Non-cultural	
42SA8502	30	WX-117	22 cm N-S 24 cm E-W	40-45
42SA8502	31	WX-116	30 cm diameter	40-50 (?)
42SA8506	32	EX-97,103, 104,107, 108,109	300 cm N-S	18-40
42SA8506*	33	EX-103,107, 108	40 cm N-S 120 cm E-W	10-55
42SA8506*	34	EX-97,108	75 cm N-S 75 cm E-W	32-60
42SA16858*	35	EX-146	70 cm N-S 50 cm E-W	45-65
42SA8506*	36	EX-97	30 cm N-S 28 cm E-W	50-55
42SA8506	37	EX-97	45 cm N-S 55 cm E-W	35-48
42SA8506*	38	EX-97	10 cm diameter	50-60 (?)
42SA8506*	39	EX-97,109	162 cm N-S 115 cm E-W	50-90
42SA16858	40	EX-168,173	46 cm N-S 34 cm E-W	85-116

Table 17. Concluded.

Site	Feature Number	Excavation Units	Dimensions	Depth (in cm below datum)
42SA16858*	41	EX-173	40 cm diameter	21-50
42SA8503	42	WX-235	125 cm N-S 125 cm E-W	5-9
42SA8500	43	EX-261	77 cm N-S 87 cm E-W	0-21
42SA8500	44		Non-cultural	
42SA8500*	45	EX-268	80 cm N-S 90 cm E-W	0-5
42SA8500*	46	EX-269	90 cm N-S 88 cm E-W	0-32
42SA8500*	47	EX-271,272	96 cm diameter	9-71
	48	EX-287,288	55 cm N-S 60 cm E-W	0-15
	49	EX-289,294	105 cm diameter	0-18
42SA415	50	EX-292,297	90 cm N-S 80 cm E-W	1-50
42SA415	51	EX-292,297	32 cm N-S 37 cm E-W	0-1
42SA415	52	EX-293	Non-cultural	
42SA8512	53	WX-272	35 cm N-S 47 cm E-W	5-20
42SA8512	54	WX-280,281	40 cm N-S 60 cm E-W	35-40
42SA8512	55	WX-280,294	30 cm N-S 35 cm E-W	5-15
42SA8512*	56	WX-290,295	55 cm N-S 57 cm E-W	51-58

*Radiocarbon dates for these features are presented in Table 16.

Table 18. Codesheet for archeological feature database file.

FIELDS

Feature Number

Provenience Data
E or W
Unit - unit containing the major part of the feature when it lay in more than one unit.

Site
Top - elevation of feature exposure
Base - lowermost feature elevation

Dimensions
N/S - measurement on north/south axis or long axis of feature (in centimeters)
E/W - measurement on east/west axis or perpendicular to long axis of feature (in centimeters)

Shape
Plan
1 - circular
2 - oval
3 - irregular
4 - semi-circular
5 - unknown
6 - polygonal

XSec
1 - basin
2 - irregular
3 - tabular
4 - no cross section
5 - cylindrical
6 - cone, contracting walls

Descriptive Data
Strat
0 - not stratified
1 - stratified
2 - mixed soil types, mottled

Dist
0 - none
1 - rodent disturbance
2 - roots
3 - rodent and root disturbance
4 - general bioturbation, type disturbance not specified
5 - other

CSam
0 - charcoal not collected
1 - charcoal collected

SSam
0 - soil not collected
1 - soil collected

Table 18. Concluded.

PSam
0 - pollen not collected
1 - pollen collected

Contents
0 - no artifacts
1 - burnt bone
2 - unburnt bone
3 - human bone
4 - faunal bone
5 - lithic debitage
6 - lithic tools
7 - ceramics
8 - ground stone
9 - fire-cracked rock
10 - macrofloral
11 - other (see comments)
22 - historic debris

Slb
0 - slabs absent
1 - slabs present

Date
Corrected radiocarbon date (95% confidence level)

Code
1 - charcoal and/or ash stain
2 - hearth
3 - pit
4 - rock alignment
5 - unidentified
6 - olla and pit
7 - burnt log(s)
8 - human burial

Comments

Ten sandstone rocks were aligned in a semicircle along the southwest edge of a small rock outcrop. The rocks were generally not more than 20 cm wide and extended to a depth 15 cm below the surface. A second line of seven rocks oriented from north to south was exposed from 5 to 10 cm below the surface. It is not known if these rocks are associated with the feature visible on the ground surface. Chert flakes were recovered from high-density deposits within and without the rock semicircle. A few bone fragments were collected. Several ground stone fragments were recovered from Unit 14W exterior to Feature 4 (T14-1W, T14-36W). Feature fill was a loose sand ranging in color from reddish brown to yellowish red (no Munsells from feature, but from unit west wall—5YR 5/4, 5YR 4/4, 5YR 5/6). Although similar to outside unit fill, interior sediments exhibited more mottling. A soil sample was collected.

Feature 5, 42GR2025

Feature 5 was an irregularly shaped dark stain visible on the surface of Excavation Unit 54W (2x2 meter). The unit was located at the Knoll (42GR2025). The stain's maximum extent measured 76 cm from east to west and 98 cm from north to south. Feature fill consisted of a mottled grayish brown ash and charcoal mixed with sand (10YR 5/2, 10YR 4/2, 10YR 4/1) and fire-blackened rocks extending to a maximum depth of 14 cm. A charcoal sample from the feature yielded a calibrated radiocarbon date of A.D. 900-1205 (Table 16). Artifacts recovered from the feature include a projectile point fragment (T54-21W), flakes and bone fragments. The unit around the feature also contained lithic tools and debitage. Soil samples were collected.

Feature 6, 42SA8502

Feature 6 was an irregularly shaped charcoal stain visible on the surface of Excavation Unit 54E. The unit was located on the east side of the Neck (42SA8502). The stain's maximum extent was 110 cm from north to south and 113 cm from east to west. The stain expanded to its maximum size at 5 cm below the surface and then began contracting. It extended to 15 cm bs. Many artifacts were associated with the feature, including flakes, lithic tools, burnt ceramics (T54-5E), burnt and unburnt bone fragments, and a cow or bison mandible (T58-8E). Projectile points, both whole and partial, were recovered within the feature (T54-22E, T54-28E) and the surrounding unit, including several Desert Side-notched points. A large quantity of fire-cracked rock, both sandstone and chert, was also scattered in the feature. Root and rodent disturbance was noted. A charcoal sample from the feature yielded a calibrated radiocarbon date of A.D. 1425-1655 (Table 16). One bulk soil sample was collected.

Feature 7, 42SA8502

Feature 7, a hearth, was the first feature identified at the large block excavation on the east side of the Neck (42SA8502). Ten other features, mostly anomalous charcoal stains, were also found in this area (see Features 11-14, 16, 18, 19, 22, 23, 25). Feature 7 was visible on the ground surface in Unit 55E. It was mapped at 5 cm below surface as measuring 105 cm from north to south and 64 cm from east to west. During excavation, it was found to be much smaller than originally thought, 28 cm from north to south. At this point, only the feature's east half has been excavated and its width remains unknown. Feature fill was 7 cm thick with a basin-shaped cross section. Fill consisted of a black sand matrix (10YR 2/1) containing charcoal, fire-cracked and blackened sandstone, burnt and unburnt bone fragments, and lithic debitage. A charcoal sample from the feature yielded a calibrated radiocarbon date of A.D. 1235-1415 (Table 16). Bulk soil samples were collected.

Feature 8, 42SA8502

Feature 8 was an irregularly shaped charcoal stain in Excavation Unit 56E (2x2 meter) on the east side at the Neck (42SA8502). It was visible on the surface of the unit, but remained ill-defined until exposed at 10 cm bs. At maximum extent (8 cm bs), it measured 84 cm from north to south and 96 cm from east to west. The feature had an irregular basin-shaped cross section which extended to 15 cm bs. The fill was a loose brown sand (7.5YR 5/4). Feature contents included flakes, and burnt and unburnt bone. A projectile point tip (T56-22E) was recovered nearby. Fire-cracked sandstone and chert fragments were scattered in and around the periphery of the stain. Feature 8 could have been discarded hearth fill. Charcoal and bulk soil samples were collected. Feature 8 lay in proximity to Feature 17, another dark charcoal stain.

Feature 9, 42SA8502

Feature 9 was a basin-shaped hearth in Excavation Unit 57E (2x2 meter) located 10 meters east of the road, 10 meters south of Transit Station 46E, in 42SA8502 site area. A circular configuration of sandstone and scattered charcoal was visible on the ground surface. At 5 cm bs, the outlines were defined and measured 70 cm from north to south and 49 cm from east to west. Fill extended to 13 cm bs and consisted of a light reddish-brown sand (5YR 6/4). Its boundaries were somewhat mottled and indistinct. The feature contained scattered charcoal and partially carbonized wood. No artifacts were recovered from the feature, although it was located within a dense surface lithic scatter. Some fragments of newspaper containing 1954 and 1955 dates were observed just north of the feature. No charcoal or soil samples were collected.

Feature 10, 42SA8502

Feature 10 was a basin-shaped hearth located in the north half of Unit 91W (Figure 44). The unit lay 40 meters from the Neck Spring Trail Head within the area of site 42SA8502. A roughly circular stain with scattered fire-cracked rock was visible on the surface. On the ground surface, the hearth measured 60 cm from north to south and 57 cm from east to west. It contracted to 44 cm from north to south and 48 cm from east to west at a 5 cm depth. Feature fill continued to a depth of 15 cm bs. It consisted of a black sand matrix (5YR 2.5/1) with charcoal staining and flecking and scattered pieces of fire-cracked chert and sandstone. The feature's contents included a flake and a bone fragment. A projectile point fragment (T91-13W) was recovered nearby. Charcoal and bulk soil samples were collected.

Feature 11, 42SA8502

Feature 11 was an anomalous dark stain located in the block excavation on the east side of the Neck (42SA8502). It was exposed at 10 cm bd in Units 55E, 58E, and 61E. The stain had a roughly circular shape, 65 cm in diameter. The feature's cross section was irregular and showed fill 9 cm thick. Fill consisted of a mottled dark reddish brown sand (7.5YR 3/2 mottled with 7.5YR 4/2, 5/4) with charcoal. Feature 11 was located east of, and immediately adjacent to, Feature 23. The two features were very similar in fill color and texture. The feature contained burnt and unburnt bone fragments and blackened sandstone. Charcoal and bulk soil samples were collected. Some root activity was observed.

Feature 12, 42SA8502

Feature 12 was a shallow charcoal stain located in the block excavation on the east side of the Neck (42SA8502). It covered an area over the intersection of Units 55E, 60E, and 62E. The stain had an irregular outline and measured 36 cm from north to south and 29 cm from east to west. It was exposed at an elevation of 2 cm bd and contained fill up to 3 cm thick. Fill was a

Figure 44. Exposed surface of small pit, Feature 10, 42SA8502.

dark reddish brown silty sand (7.5YR 3/2) in which some root activity was present. One bone fragment was recovered. A soil sample was collected.

Feature 13, 42SA8502

Feature 13, in Unit 55E at the block excavation on the east side of the Neck (42SA8502), was a shallow circular charcoal stain. It was exposed at 1 cm bd in Excavation Unit 55E. The stain measured 23 cm in diameter and contained 1 to 2 cm of fill. Feature fill was a dark reddish brown silty sand (7.5YR 3/2). Bioturbation had apparently disturbed the base of the feature. No artifacts were recovered from the stain. Bulk soil and charcoal samples were collected.

Feature 14, 42SA8502

Feature 14 was a dark circular charcoal stain surrounded by an irregularly shaped lighter ash stain. Located on the east side of the Neck (42SA8502), the feature was exposed in Units 58E, 59E, 63E, and 64E. The upper surface of the feature was contacted at 5 cm bs (3 to 13 cm bd). It measured 108 cm from north to south and 110 cm from east to west. The feature had a basin-shaped profile ranging from 2 to 9 cm in thickness. The internal dark circular stain, possibly a hearth, was 40 cm in diameter. Its fill, which was thicker than the surrounding ash, was brown to dark brown (7.5YR 4/2) with charcoal. The outer ring contained sand and ash fill ranging from light to dark gray (10YR 6/1, 4/1). The shallowest portion of the deposit (2-3 cm thick) was on the north and west sides. It contained more artifacts than the central "hearth." The feature's contents included burnt and unburnt bone fragments, burnt sandstone, flakes, and pinyon nut shells. A charcoal sample yielded a calibrated radiocarbon date of A.D. 1655-1950 (Table 16). The integrity of the feature had been affected by disturbance from black brush roots and leaching. Parts of a broken metate (T59-11E, T59-13E) were recovered near the feature's surface. One fragment lay over the "hearth" area. Soil and charcoal samples were collected.

Feature 16, 42SA8502

Feature 16 was another shallow, irregularly shaped charcoal stain located on the east side of the Neck (42SA8502). It extended into the south wall of Unit 63E, and the full extent of the feature was not excavated. As exposed, it measured 36 cm from north to south and 18 cm from east to west. The stain was contacted at 14 cm bd and had fill from 2 to 4 cm thick. The fill was a light brown sand (7.5YR 6/4) with charcoal staining and flecking. Several bone fragments were recovered. Bulk soil and charcoal samples were collected.

Feature 17, 42SA8502

Feature 17, an amorphous charcoal stain, was located in Excavation Units 56E and 66E in close proximity to Feature 8. It was contacted at 10 cm below the surface and had a basin-shaped fill up to 10 cm thick. In plan view, the feature measured 70 cm north-south and 84 cm east-west. The feature contained a brown, charcoal stained, sandy fill (7.5YR 5/4) with charcoal concentrations, fire-cracked chert and sandstone, and several bone fragments. Soil samples, not charcoal samples, were collected.

Feature 18, 42SA8502

Located at the block excavation on the east side of the Neck (42SA8502), Feature 18 was a circular dark charcoal stain (7.5YR 3/2). In Excavation Unit 55E, Feature 18 lay west of another similar circular stain, Feature 19. Feature 18 was contacted at 0 cm bd and had a 10 cm diameter. The fill had an irregular cross section measuring 5 cm in thickness. One bone fragment was recovered from the stain. A soil sample was collected.

Feature 19, 42SA8502

Feature 19, 1 cm to the east of Feature 18, was a circular charcoal stain. It was exposed at 1 cm bd and had an irregular cross section up to 8 cm thick. The stain had an 8 cm diameter and contained fill of a slightly lighter color than Feature 18 (7.5YR 3/2). No artifacts were recovered. A soil sample was collected.

Feature 22, 42SA8502

Feature 22 was an ash and charcoal stain discovered in profiling Feature 7. It lay north of Feature 7. The feature measured 18 cm from north to south and 22

cm east-west. Since part of the feature was excavated while cross-sectioning Feature 7, its plan shape remains unknown. The stain's surface and base lay at 4 and 9 cm bd, respectively. It had a basin-shaped cross section. Feature fill consisted of black sand (10YR 2/1) with charcoal. No artifacts were recovered. No samples were collected.

Feature 23, 42SA8502

Feature 23 was a shallow, irregularly shaped charcoal stain located in the block excavation on the east side of the Neck in Units 58E and 63E. When first exposed, it measured 56 cm from north to south and 33 cm from east to west. The stain was contacted at 15 cm bd and was 5 cm thick. It was located immediately to the west of Feature 11, which exhibited similar characteristics. The fill was brown to dark brown sand (7.5YR 4/2). Numerous burnt bone fragments were collected from the stain area. Several microflakes were also recovered. Charcoal and bulk soil samples were collected.

Feature 25, 42SA8502

Feature 25 was a basin-shaped charcoal concentration 12 cm west of the south end of Feature 7 in Excavation Unit 55E. The circular stain was exposed at 11 cm bd. It had a 12 cm diameter and 6 cm of fill. The feature contained mottled reddish yellow and black sand with charcoal. Two pieces of debitage were recovered. Soil and charcoal were not collected.

Feature 26, 42SA8502

Feature 26, in the block excavation on the west side at the Neck (42SA8502), was an oval-shaped charcoal stain, within which lay a circular lens of fire-reddened fill. Located in Units 93W, 94W, 102W, and 103W, it was first exposed at 45 cm bd and its base lay on bedrock, at 48 to 50 cm bd. The charcoal stained fill measured 102 cm north-south and 100 cm east-west. The oxidized lens (2.5YR 4/4) within the stained area, probably a hearth, had a basin-shaped cross section and measured 20 cm from north to south and 22 cm from east to west. Feature fill consisted of very fine sand (7.5YR 3/2) with charcoal staining. The feature's contents included burnt and unburnt bone, pieces of burnt sandstone, a burnt seed, flakes, microflakes, and point fragments. Several primary flakes exibited cortex that was reported to be similar to other unworked rocks located in the feature fill. One Desert Side-notched point base (T93-8W) was recovered. Several bulk soil samples were collected. Charcoal recovered from the feature yielded a calibrated radiocarbon date of A.D. 1420-1655 (Table 16).

Feature 27, 42SA8502

Feature 27 was located at the the block excavation on the east side of the Neck (42SA8502) close to the surface of Units 64E and 65E. After a black brush was removed from the ground surface, the feature was no longer visible.

Feature 28, 42SA8502

This feature was one of several amorphous zones of charcoal staining located on the west side of the Neck (42SA8502). Feature 28 was located in Units 97W and 98W. The feature measured 66 cm from north to south and 63 cm from east to west at 45 cm bd. It was encountered at 43 cm bd and its base rested upon bedrock. Bedrock in the immediate area sloped down to the south and was encountered at various depths from 45 cm to 56 cm. At 50 cm bd, the stain had contracted into an oval-shaped pocket in the south half of Unit 98W. As shown in the cross section, fill varied from 3 to 8 cm in thickness. The feature contained burnt and unburnt bone fragments and flakes. Soil samples were collected. A charcoal sample yielded a modern radiocarbon date for the feature. Notably, a significant amount of root activity was observed directly on top of bedrock, generally originating from the juniper tree in close proximity to the excavation units. These large roots had possibly created an unknown amount of vertical and horizontal displacement in this and the other features (26, 30, 31) at this block excavation.

Feature 30, 42SA8502

Feature 30 was another amorphous charcoal stain located on top of bedrock on the west side of 42SA8502. The feature was located in the west half of Unit 117W, and measured 20 cm north-south and 24 cm east to west. The fill extended from 40 to 44 cm bd. One unburnt bone fragment was recovered from the

feature. More bone fragments were collected close by. The feature was dissected by several large roots. A large rock was located directly east of Feature 30. Charcoal samples were collected.

Feature 31, 42SA8502

Feature 31 was an amorphous charcoal stained area similar in nature to Features 28 and 30. It was located in the east half of the southeast quadrant of Unit 116W. As mapped, the stain measured 50 cm from north to south and 32 cm from east to west. It appeared to extend south and east into adjacent units. However, it is not documented in those units (97W, 98W, 117W). The feature was identified as a concentration of bone fragments associated with some scattered charcoal staining. Tooth fragments and flakes were also found in association with the feature. No samples were collected. This feature was unfortunately poorly documented, possibly because of its exceedingly amorphous nature. Features 28 and 30 are located in the aforementioned units at this elevation, and very possibly are interrelated.

The features on the west side of the Neck all had several characteristics in common. First, they all were positioned directly on top of bedrock. Secondly, they all had experienced some amount of root disturbance. Thirdly, they were covered by about 30 to 35 cm of relatively homogeneous, non-cultural fill. Possibly they are not individual features, but represent some kind of activity surface, albeit disturbed. Or the collection of artifacts and stained sediments may have resulted through natural processes, brought into this lower-lying area by rain and wind, to collect in pockets on top of bedrock.

Feature 32, 42SA8506

The first feature identified at the Dunes block excavation (42SA8506) was Feature 32, a large anomalous mottled stain. It was originally observed at 8 cm below surface (18 cm bd) in the west half of Excavation Unit 97E (2 x 2 meters). When the boundaries were exposed, the feature extended into eight excavation units (97E, 103E, 104E, 107E, 108E, 109E, 110E, 111E). At 20 cm bd, the stain measured 265 cm from north to south and 265 cm from east to west. The basal extent of the feature was not distinct. The zone of dark mottled staining began to contract at about 40 cm bd, especially in the north half of 97E. Staining continued in Units 97 and 104, at least to a depth of 50 cm bd. Feature fill was not stratified and consisted of a fine sand in a range of colors from yellowish red to reddish brown (5YR 5/6, 5YR 4/4, 7.5YR 5/6) with varying quantities of charcoal. It contained a high bone content (both human and faunal), pottery sherds, pieces of burnt and nonburnt sandstone. Rodent burrows intruded into the feature at varying depths. Charcoal, bulk soil, and pollen samples were collected from the feature. The zone of mottled fill identified as Feature 32 also included Features 36, 37, and 38. The southwest edge of Feature 32 borders on Feature 33 and Feature 34. It is as yet unknown how the features at the Dunes were interrelated prehistorically, due to their extremely confusing nature. See descriptions of Features 33, 34, 36, 37, 38, and 39 for further details. Feature 32 fill contained the greatest artifact density at the Dunes block excavation. Outside of Feature 32 there was a paucity of cultural material towards the south and west, but a noticeable scattering of artifacts towards the northeast. The southeastern portion of Feature 32 was apparently dissected by a refuse pit, Feature 39 (see Feature 39 description).

Several possible explanations for Feature 32 have been explored. Because of the location of the site within sand dunes, it is likely that the site has experienced horizontal and vertical displacement as a result of dune activity. Thus, the nature of Feature 32 may have resulted from this type of disturbance to an original activity surface. Another possible explanation is that the amorphous appearance of Feature 32 was created as a result of mechanical disturbance to Feature 33 on the southwestern boundary of Feature 32. If some kind of mechanical disturbance took place at the Dunes, it apparently did not reach deep enough to affect the corrugated pot located near Feature 33 or the articulated portion of the human burial in Feature 34. The pot (T104-8E), located from 40 to 50 cm bd, was apparently broken in place and had not been scattered by disturbance. Although the majority of the human burial had apparently been disturbed by the prehistoric excavation of Feature 39, it seems unlikely that the articulated human left leg bones in Feature 34 had been subject to any direct disturbance.

Feature 33, 42SA8506

Feature 33 was a semicircular configuration of several large burnt logs and a zone of charcoal stained sediments at the Dunes block excavation (Figures 45-49).

It was originally contacted relatively close to the surface (about 10 cm bd) in Excavation Unit 108E. The feature extended to the east into Unit 109E and to the northwest into Units 107E and 104E. It was 200 cm long from southeast-northwest and measured 75 cm at its widest. The logs were generally oriented horizontally, and they occurred at to varying depths, 55 cm bd being the deepest. A radiocarbon sample from one of the logs yielded a calibrated radiocarbon date of A.D. 895-1195 (Table 16). This date overlaps with the radiocarbon dates for Feature 38, another burnt log or "post," and Feature 39, a large refuse pit intrusive to Feature 32. Samples for wood identification were also collected. The surrounding fill was mottled, lightly compact, fine sand, brown to black in color (7.5YR 3/0, 5YR 2.5/1, 2.5YR 4/4). The quantity of cultural material associated with Feature 33 was significantly less than that of Feature 32, possibly indicating a natural rather than cultural origin for the logs. Burnt and unburnt bone fragments were recovered from the feature area. A broken, yet almost complete, corrugated pot (T104-8E) was found in close proximity to the feature in the south half of Unit 104E from 40 to 50 cm bd. Charcoal stained soil lay around and below the pot, but not over it. The pot does not appear to have experienced excessive burning, though one of the logs lay within 5 cm to the west. The recovered artifacts' association with the burnt logs remains unclear. Feature 33 was located along the southwestern boundary of Feature 32, but the relationship between them remains unknown (see Feature 32 description). In addition, the association between Feature 33 and Feature 34 is ambiguous, where, in Unit 108E, Feature 33 overlapped the southern edge of Feature 34 at 40 to 45 cm bd (Figure 46).

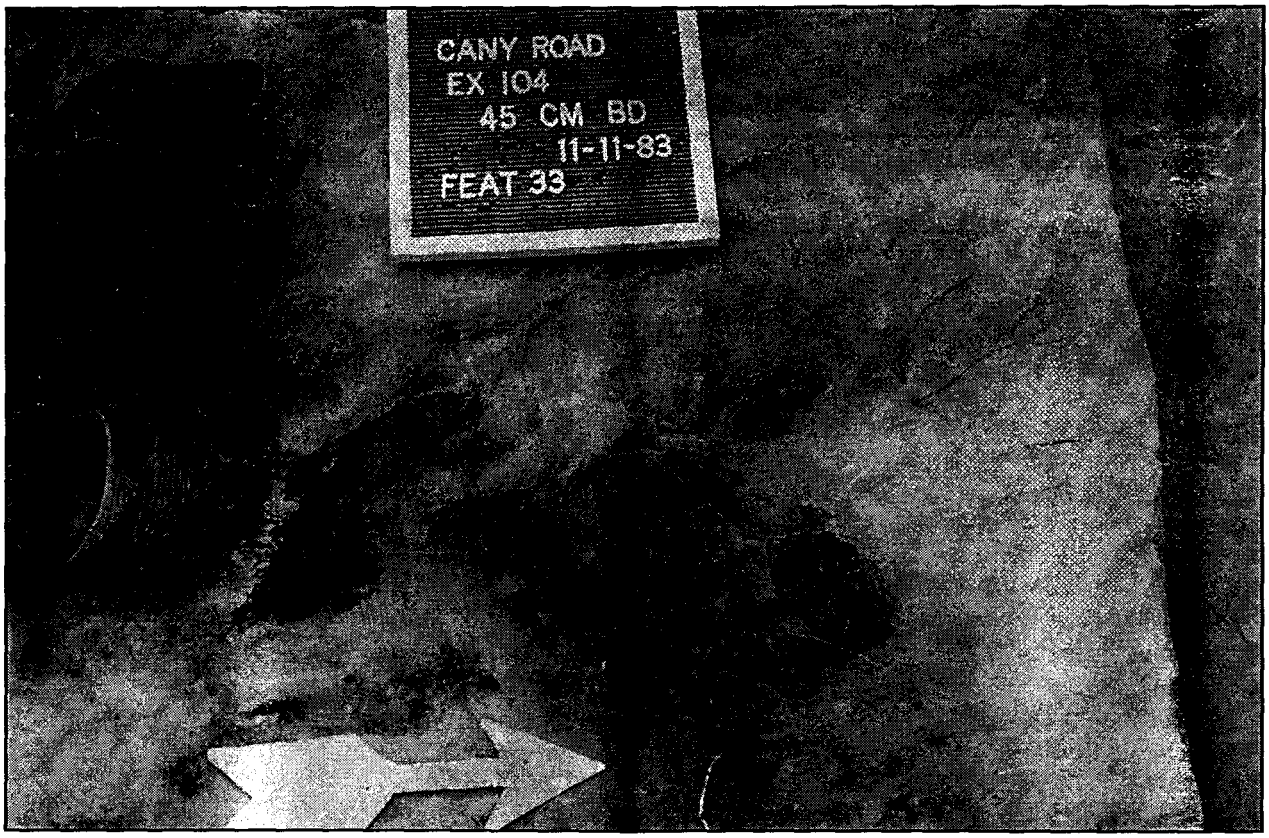


Figure 45. Detailed view of Feature 33, 42SA8506, showing corrugated vessel.

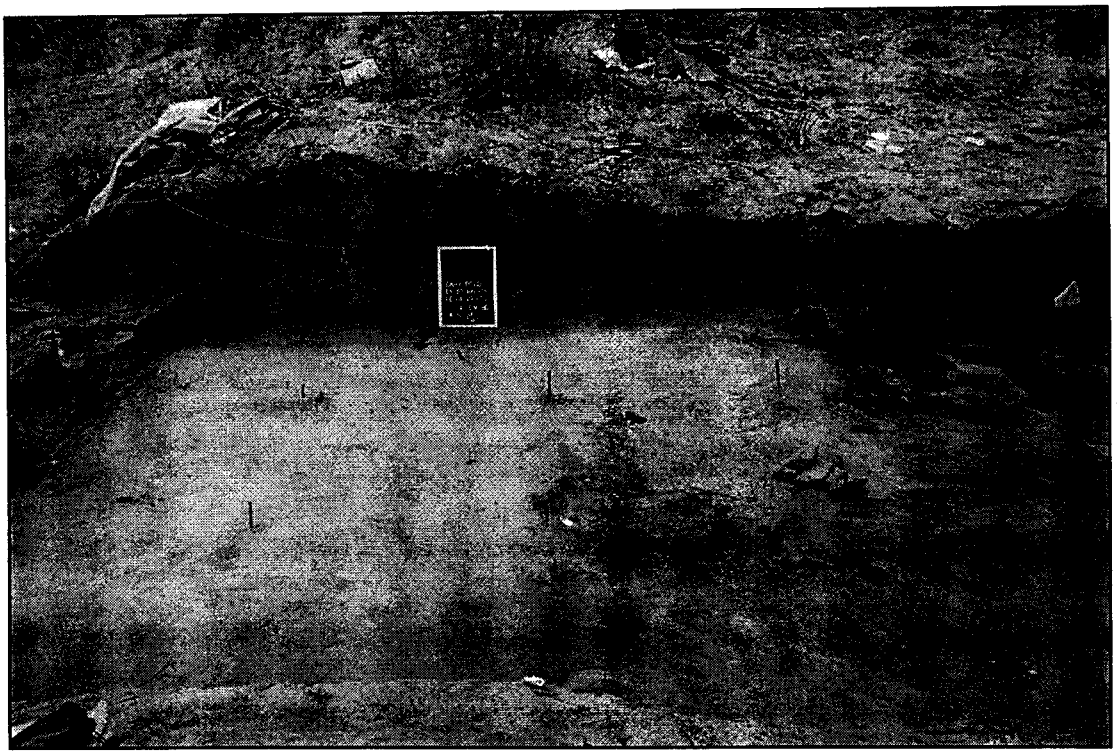


Figure 46. Exposure of Features 33 and 34, 42SA8506, view to the sourth.

Figure 47. General view of the exposed surfaces of Features 33 and 34, 42SA8506, view to the east.

Feature 34, 42SA8506

Feature 34, at the Dunes block excavation, was a partially intact human burial overlain by several sandstone slabs (Figures 48 and 49). The overlapping sandstone slabs were initially contacted underlying a portion of Feature 33 in the north half of Unit 108E. The uppermost and lowermost slab elevations were 35 cm and 53 cm, respectively. Human bone was recovered from 41 cm to 59 cm bd. The feature measured 95 cm north-south and 85 cm east-west. It had an irregular outline, with no discernable pattern for the slabs' positions. There were six major slabs, three dipped toward the northwest, and three to the southeast. The slabs are burned and blackened. The westernmost slab (T108-72E) is broken into seven pieces, and has eight small ground holes on the western edge of its upper face. A second slab underlying T108-72E also exibits small ground holes. The fill associated with the slabs was generally lightly mottled sand, with some areas of heavier charcoal staining (5YR 2.5/2, 5YR 3/2, 7.5YR 5/4). A charcoal sample from on top of the slabs yielded a calibrated radiocarbon date of A.D. 620-895 (see Table 16), indicating possible contemporaneity with Feature 36, a charcoal and ash filled pit in Unit 97E. A partially disturbed human burial was exposed, lying beneath and around the sandstone slabs (see Appendix B). Articulated bones included a left femur, patella, tibia, fibula, and acetabulum fragment. The femur lay oriented proximally to the northeast and distally to the southwest. More bones lay just to the north of the femur's proximal end. These included a right fibula (almost complete), a talus, and a metatarsal. The fibula lay with its distal end to the south-southwest and proximal end pointing to the north-northeast, actually appearing to dissect the wall of Feature 39. Removal of the femur revealed a metatarsal, tarsal, and calcaneous, also apparently articulated. Other unarticulated human bones lay scattered underneath the slabs, including metatarsals, phalanges, and pelvic fragments. The bones were unburned. Several other pelvic fragments were located within 20 cm west of the articulated bones just within the eastern boundary of Feature 34, close to the western periphery of Feature 39. Another group of bone fragments, including ulna, radius, and humerus fragments, was located approximately 40 cm southeast of the articulated bones, between 40 and 45 cmbd. The fragments lay above a smaller sandstone slab positioned to the southeast of the three major slabs. Human bone was also recovered outside of Feature 34, mostly in Feature 39 and Feature 32. Although it seems likely that these scattered bones belong to one individual, it has not been conclusively established. Several corrugated pottery sherds and a biface fragment (T108-88E) were recovered within the immediate area which have an unclear association with the burial. Soil samples were collected.

Feature 35, 42SA16858

Feature 35 was a hearth encircled by a U-shaped configuration of fire-hardened earth at the Gray's Pasture block excavation (42SA16858) (Figures 50 and 51). It was located in Excavation Unit 146E and first contacted at 55 cmbd. The feature measured 66 cm north-south, 46 cm east-west, and was 20 cm thick. A U-shaped rim of yellowish red (5YR 4/6), hard-packed clay/sand formed the feature walls on all but the west side. This rim was an average of 8 cm thick vertically and 8 cm wide. Feature fill consisted of two strata. The uppermost stratum, contacted at about 60 cmbd, was a tightly compact, brown (7.5YR 5/4) ash and charcoal layer that was 10 to 15 cm thick. Charcoal was more abundant in the upper portion of this stratum. A sample from this layer yielded a calibrated radiocarbon date of A.D. 610-1020 (Table 16). The underlying stratum was a basin-shaped lens of tightly compact, oxidized sand deposit (5YR 5/6) which averaged 6 cm in thickness. The fill thinned out on the west side where there was no rim. Several pieces of fire-cracked rock (3372.6 grams) and one piece of ground stone (T146-62E) were located to the west of the ends of the fire-hardened rim. Feature samples include bulk soil, ash, and fire-hardened earth. A few burnt seeds (possibly pinyon, T146-79E) and a chunk of hematite (T146-61E) were also collected from the feature. A small number of bone fragments and flakes were recovered. In close association with the feature were three McElmo Black-on-white sherds (Vessel GC) and a metate (T147-44E) with two manos (T147-45E, 46E-both missing) positioned on its surface.

Feature 36, 42SA8506

Feature 36, at the Dunes (42SA8506), was a basin-shaped charcoal stain in Unit 97E. It was located below part of Feature 37, an ash lens that appeared intrusive to Feature 36. Dark mottling in the center of the west half of Unit 97E had been noted at 35 cm bd. This staining was possibly related to Feature 36 and/or

Figure 48. Exposure of Features 33 and 34, 42SA8506, at 45 cm below datum showing burned sandstone slabs and pit outline.

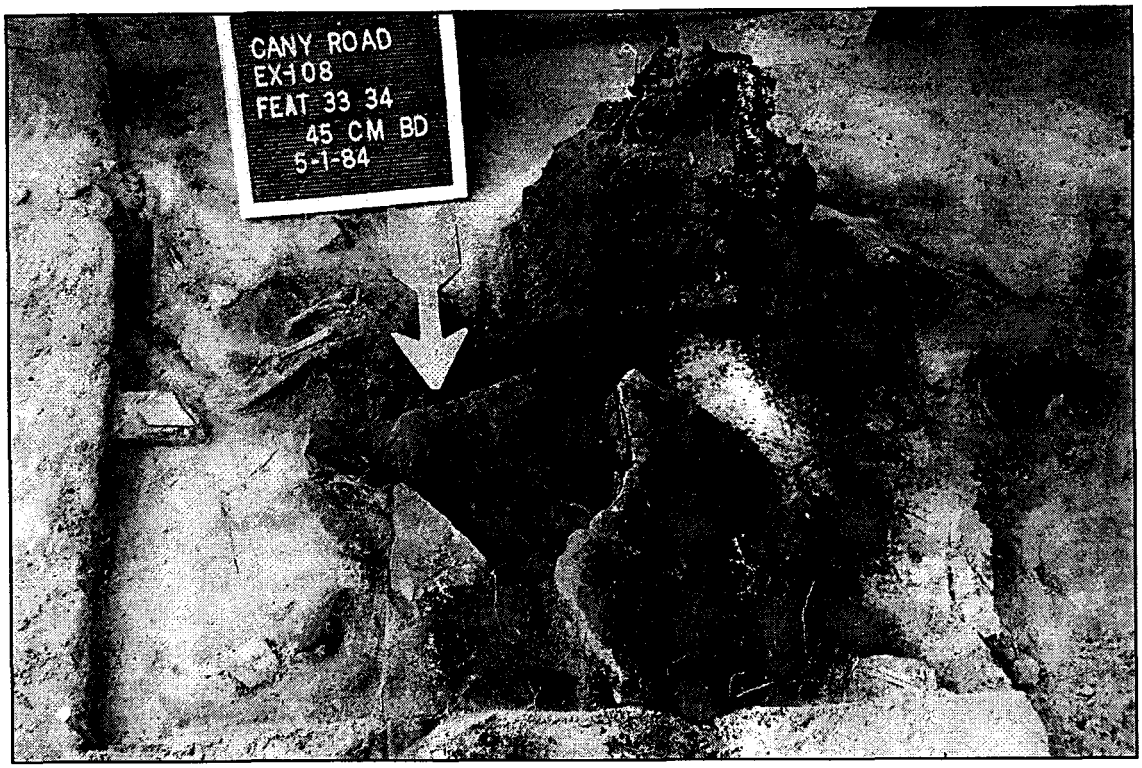


Figure 49. Detailed view of Features 33 and 34, 42SA8506, showing human remains left of north arrow.

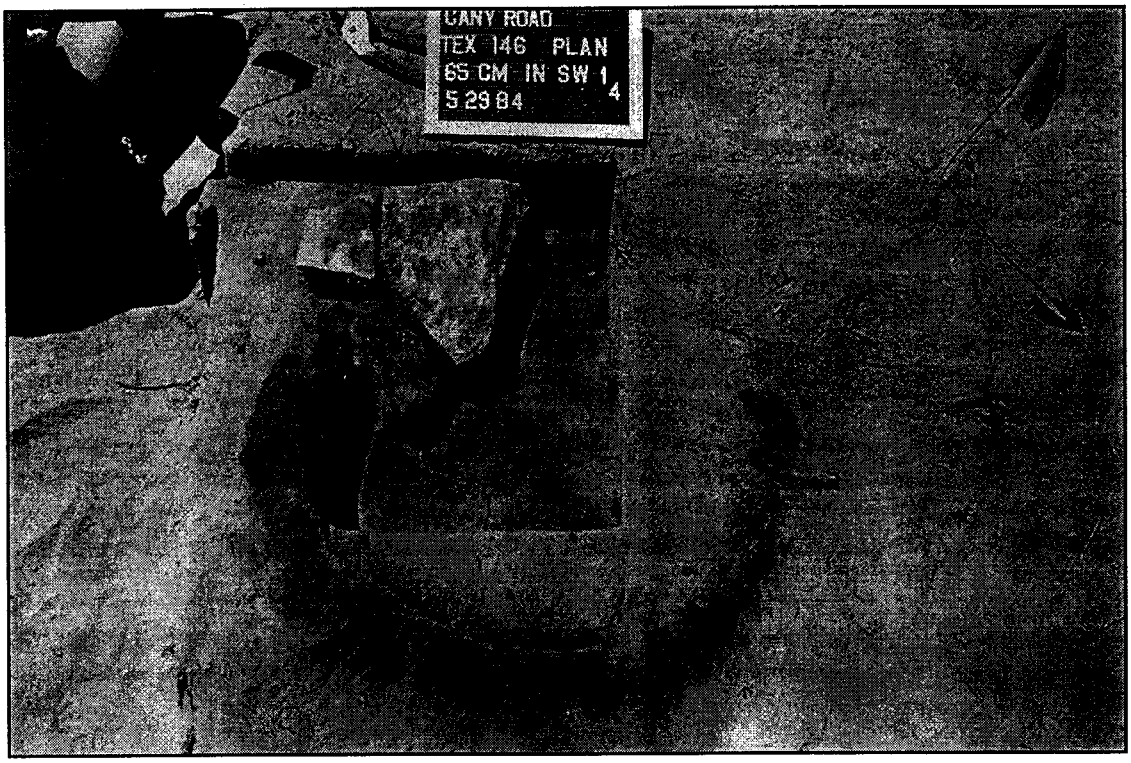


Figure 50. Excavated clay-lined hearth, Feature 35, 42SA16858.

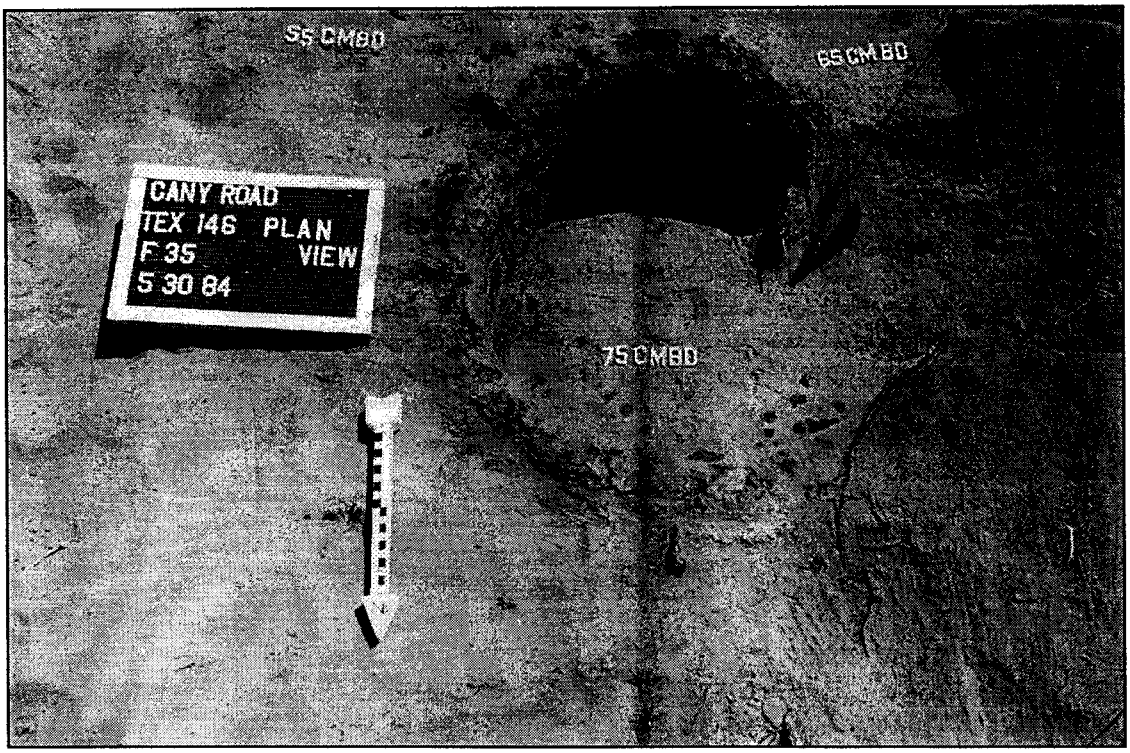


Figure 51. Plan view of clay-lined hearth, Feature 35, 42SA16858.

Feature 37. Feature 36 was identified at 50 cm bd. It had a 30 cm diameter and 9 cm of fill depth. The feature fill consisted of mottled sediments (7.5YR 4/2) and charcoal chunks surrounded by an amorphous zone of mottled gray ash (5YR 4/1). A charcoal sample from the central fill yielded a calibrated radiocarbon date of A.D. 585-900 (Table 16). Pieces of sandstone were scattered in the feature. Several soil samples were collected. One pot sherd (T97-312E) was collected from the feature.

Feature 37, 42SA8506

Feature 37, in the west half of Unit 97E at the Dunes block excavation, was a shallow, irregularly shaped ash lens. As previously noted, Feature 37 was located above and apparently intrusive to Feature 36. The feature was identified at 45 cm bd and was excavated to 48 cm bd. The stain measured about 25 cm from east-west and 15 cm north-south. The fill was a whitish gray ash (10YR 2/1, 3/3, 4/1) without any charcoal. A soil sample was collected. No artifacts were recovered from the fill.

Feature 38, 42SA8506

Feature 38 was possibly a partially burnt post at the Dunes block excavation. The feature was located in the northeast quadrant of Unit 97E at a distance of 25 cm northeast of Feature 36 and Feature 37. It was first observed in the 35 to 40 cm bd level and extended to over 60 cm bd. (No exact upper and lower elevations recorded.) The feature was a generally cylindrical piece of wood 30 cm long, with a 10 cm average diameter. The feature had a charred outer surface surrounding an unburnt core. The wood was not vertically oriented but had a dip of 65 degrees toward the southeast. The angle of Feature 38 suggests that its origins may be natural rather than cultural. The burnt wood was surrounded by a zone of brown ashy fill (5YR 4/4). A charcoal sample from the feature yielded a calibrated radiocarbon date of A.D. 920-1230 (Table 16). A large rodent burrow was located directly to the west of Feature 38 at 50 cm bd.

Feature 39, 42SA8506

Feature 39 was a large pit apparently intrusive to Feature 32 and to the west side of Feature 34. It was located in the north half of Unit 109E, the northeast corner of Unit 108E, and the southeast and part of the southwest quadrants of Unit 97E. Although the feature was not identified until 50 cm bd, its outline had been visible in planimetric view from a depth of 25 cm bd, but interpreted as part of Feature 32. Its outline can also be seen in the 40 cm, 45 cm, and 50 cm planimetric maps of the area. The feature had a slightly irregular oval shape, and measured 150 cm north-south and 116 cm east-west at a 50 cm bd elevation. Feature fill, basin-shaped in cross section, continued to a depth of 90 cm bd. The fill did not exhibit parallel horizontal strata, but consisted of a patchwork of irregular ovate and lenticular beds of fine, yellowish red sand, with varying amounts of dark mottling and charcoal (5YR 3/2, 5/8, 10YR 2/1, 4/6, 5/3, 5/4). These zones had more visibly defined boundaries through the upper part of the feature. More mixing of sediments occurred at the base of the pit. Feature fill was less compact and appeared to lose moisture faster than surrounding non-feature sediments. The underlying subsoil was heavily mottled and loosely compact, possibly because of leaching and bioturbation. The feature was crosscut by krotovena.

The contents of the pit included human and faunal bone fragments, ceramic sherds, lithic debitage, burnt sandstone, charcoal, and carbonized wood. Bone recovered was generally unburned. Human bone fragments were recovered from 38 to 80 cm bd within the pit. These bones appeared more concentrated along the western edge of the pit adjacent to Feature 34. They include numerous rib, vertebral, and skull fragments, and part of both the left and right ulnas. Heavy charcoal and carbonized wood concentrations were located in the base of the pit and along the south and west walls. A charcoal sample yielded a calibrated radiocarbon date of A.D. 875-1055 (Table 16). Large quantities of burnt sandstone chunks were found scattered throughout the pit. The pottery recovered was mostly corrugated, but black on white, slipped, and plain sherds were also recovered. Bulk soil samples were collected.

Feature 40, 42SA16858

Feature 40, at Gray's Pasture block excavation, was a cylindrical pit with an olla resting at its base (Figures 52-55). The pit's mouth and base lay at 62 cm bd and 116 cm bd, respectively. Its diameter was 1-2 cm larger than the olla. The olla's widest measurements are 48 cm from north to south and 52 cm from east to west.

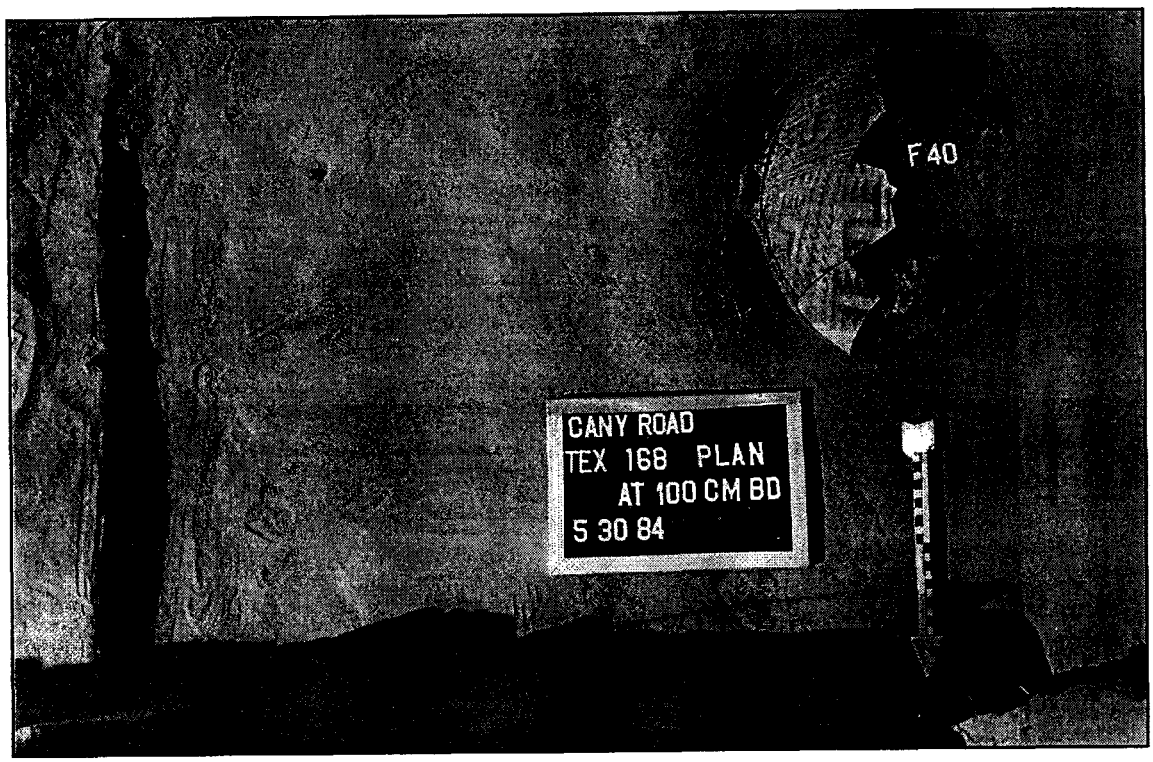


Figure 52. Horizontal profile of excavation 168, 42SA16858, showing outline of small pit (Feature 40) containing Mesa Verde Black-on-white olla.

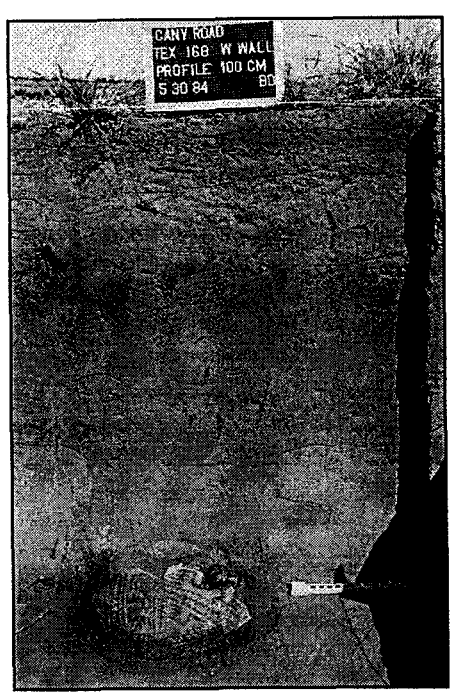


Figure 53. West profile wall of Excavation 168, 42SA16858, showing small pit (Feature 40) containing Mesa Verde Black-on-white olla.

The olla was broken into 45 sherds, the rim and neck sherds having fallen into the vessel interior. Sherds were first discovered at 86 cm bd, extending into the west wall of Unit 168E. Subsequently, the faint outline of the pit was noted in that wall. The Excavation Unit 173E was opened directly to the west of 168E to uncover the other half of the feature. The pit was visible as a slightly darker fill (5YR 5/8) than the surrounding deposit, which was a reddish yellow sand (5YR 5/6) with caliche staining. The olla handles were laterally positioned on the east and west sides at the vessels largest girth. The olla is covered with a gray slip and has carbon painted geometric designs on the exterior surface above the handles (Figures 52, 53, and 55). It is identified as a McElmo Black-on-white vessel. Several of the sherds have mending holes. The base of the olla has a generally circular opening measuring 9 cm north to south and 12 cm east to west. A sherd, broken in two, from a different vessel, covered part of the hole (T168-108E, 109E). The sherd measures 7 cm north-south and 8 cm east to west, and has B/W paint on its interior concave surface. Other feature contents include a few bone fragments, a core (T168-49E), and a burnt seed located next to the outside surface of a sherd.

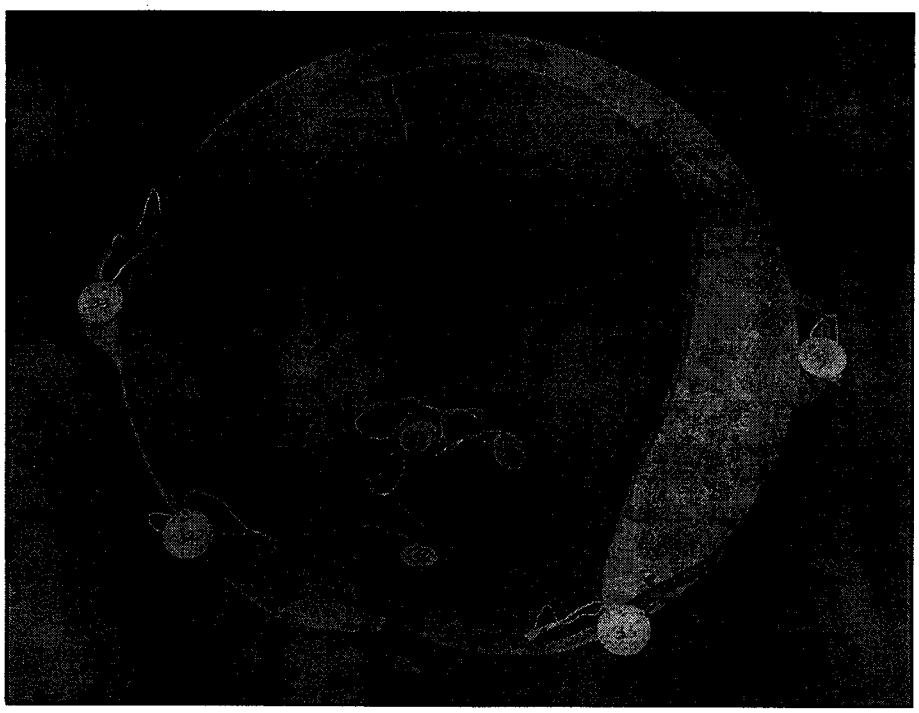


Figure 54. Interior of large Mesa Verde Black-on-white olla, Feature 40, 42SA16858, showing loose sherds used to cover missing basal portion of the vessel.

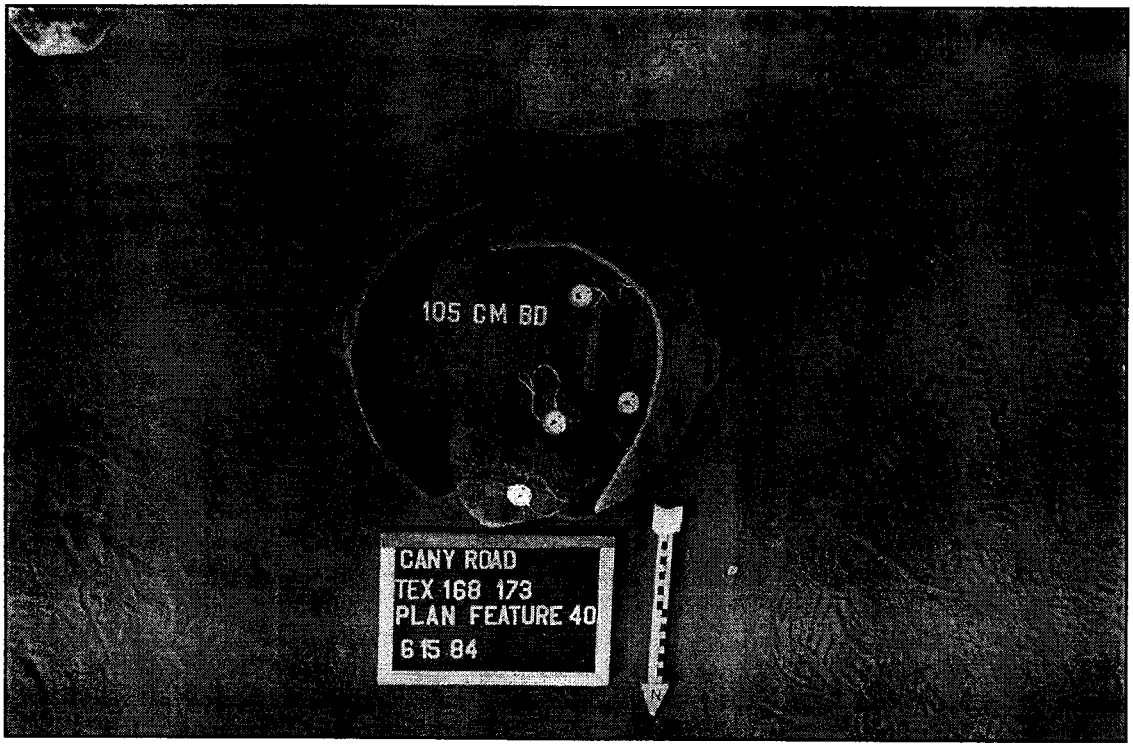


Figure 55. Completed excavation of Mesa Verde Black-on-white olla at the base of small pit (Feature 40).

Feature 41, 42SA16858

Feature 41 was a slab-lined pit located at the Gray's Pasture block excavation (42SA16858) (Figures 56 and 57). Most of the feature lay in the southwest quadrant of Unit 173E, with its southern edge extending into Unit 178E. The feature measured 35 cm north to south and 40 cm from east to west. It was first noted at 35 cm below datum as several sandstone slabs oriented in a semicircular configuration. When the unit was excavated to a 40 cm depth, most of the vertical slabs were in view. The lowest depth for slab placement was 49 cm. Eight major vertical slabs formed the wall in a generally circular arrangement. There was a 32 cm gap between slabs in the northeast section of the wall. The base was constructed with four horizontally oriented slabs. Slabs ranged in size from 49 cm tall by 25 cm wide by 3 cm thick to small rocks used for chinking. Two rocks in the center of the pit were positioned as though they had fallen in from the wall. Oxidation was noted on several rock surfaces. A section of the wall was covered with a hard, compacted mud possibly used as mortar. This material was also found in patches in the feature fill. Approximately 10 cm of fill was excavated, displaying a cylindrical cross section. The deposit was fairly homogenous in nature and similar to that found around the feature and throughout the unit (5YR 5/6). There was some mottled, charcoal stained sand in the lower feature fill. A small amount of charcoal was collected (CANY84-5, from whole pit, 40-50 cm bd, not analysed yet). The feature's contents were not necessarily indicative of its original use. One bone fragment was collected from the feature. Ground stone and ceramics were discovered relatively nearby and at a similar elevation, indicating a possible activity surface. Several bulk soil samples were taken from within the feature and directly under the basal slabs.

Feature 42, 42SA8503

Located in the vicinity of 42SA8503, Feature 42 was a shallow, disturbed, historic hearth. Scattered charcoal and nearby historic debris on the ground surface was the impetus to excavate this feature within Excavation Unit 235W. The feature outline was irregular and measured approximately 125 cm along both axes. The feature fill extended to 9 cm below the surface in some areas. It consisted of loose sand with intermixed charcoal, ash, and some patchy oxidation. Contained within the feature area were burnt bone fragments, a piece of clear glass, two cans, one nail, some fire-cracked rock, and pieces of unburnt wood. No charcoal was collected; one bulk soil sample was collected.

Feature 43, 43SA8500

Feature 43 was an oval-shaped historic hearth in Excavation Unit 261E. Its position was about 20 meters south of Murphy Point Four-Wheel Drive Road. The feature's dimensions were 77 cm from north to south and 87 cm from east to west. Feature fill was 21 cm thick. Scattered charcoal, rocks, and pieces of charred wood were visible on the ground surface. During excavation, evidence such as charcoal brickettes and aluminum foil indicated the recent age of the hearth. The pit had a basin-shaped profile with fire-cracked rocks positioned around the upper boundary. No soil or charcoal samples were collected.

Feature 45, 42SA8500

A shallow charcoal stain located within a dense surface lithic scatter near Murphy Trail (42SA8500) was designated as Feature 45. Excavation Unit 268E was established in order to investigate the feature. It lay approximately 100 meters east of Transit Station 117E and 50 meters north of the canyon rim. The feature was 80 cm north to south, 90 cm east to west, and 5 cm deep. Some scattered charcoal and fire-cracked rocks were observed on the surface. Excavation revealed an irregularly-shaped deposit of ash and charcoal intermixed with fine brown sand (7.5YR 4/2) and small gravels. One flake was recovered on the surface, but its relationship with the feature is unknown. Some disturbance of the upper fill was observed. Samples collected include bulk soil and charcoal. A charcoal sample yielded a calibrated radiocarbon date of A.D. 1425-1660 (Table 16).

Feature 46, 42SA8500

Feature 46 was the first of two slab-lined hearths excavated in the Murphy Trail (42SA8500) area (Figures 58-60). It was about 125 meters northeast of Transit Station 118E and 200 meters southeast of Station 111E. The edges of three sandstone slabs were visible on the surface along with a few scattered pieces

of fire-cracked rock. Excavation Unit 269E was set up for further exploration. The feature had an irregular pentagonal shape in plan view. It had outer measurements of 90 cm across the north/south axis and 88 cm east-west. It was constructed of nine major vertically-positioned sandstone slabs, with another nine horizontal, overlapping slabs forming the base. The north half of the pit was excavated first, revealing a profile with flat, outward sloping walls and an irregular base. The slabs displayed some blackening, resulting either from direct burning or charcoal staining. The sediment fill was 20 to 24 cm deep. It consisted mainly of a black sand deposit (10YR 2/1) containing decomposing charcoal and was crosscut by lenses of yellowish red sand (5YR 4/6) with charcoal flecking. The black deposit was described as having a "greasy" texture. There were several sandstone slabs within the feature. No oxidation of surrounding soil was observed. Several samples were collected from the feature including bulk soil for flotation and charcoal for radiometric dating. A charcoal sample yielded a calibrated radiocarbon date of A.D. 65-430 (Table 16). One burned flake (T269-3E) was collected from the fill. Several burned pinyon nut shells were observed from 10 to 15 cm bs; however, excavators noted the proximity of a pinyon tree as a possible source for the nuts. When interior excavation was complete, excavators removed the slabs and collected four pollen samples from areas behind and below them. Bedrock was encountered almost directly below the basal slabs.

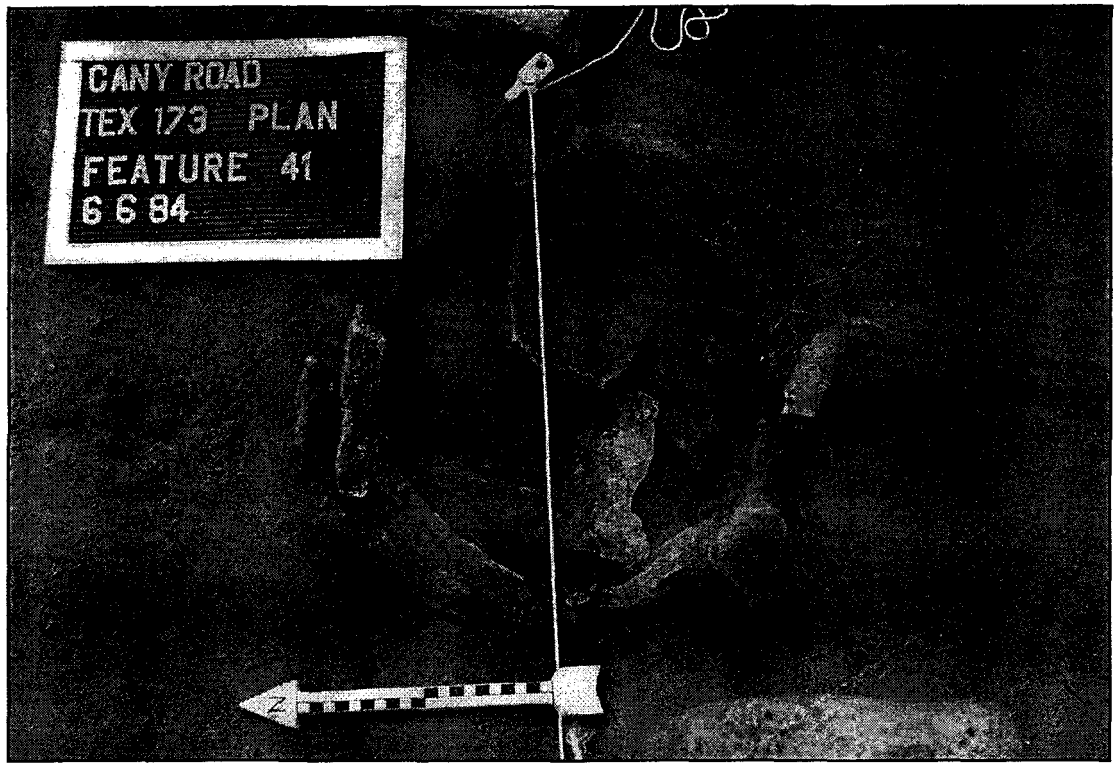


Figure 56. Completed excavation of small slab-lined Feature 41, 42SA16858.

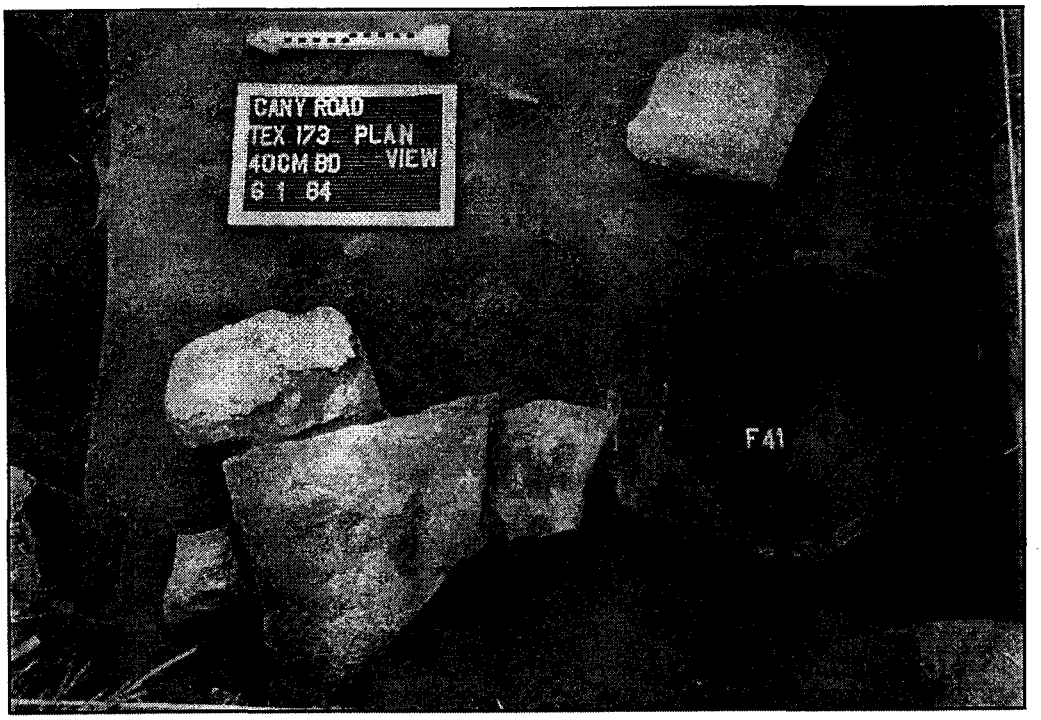


Figure 57. Exposed surface of small slab-lined feature,42SA16858.

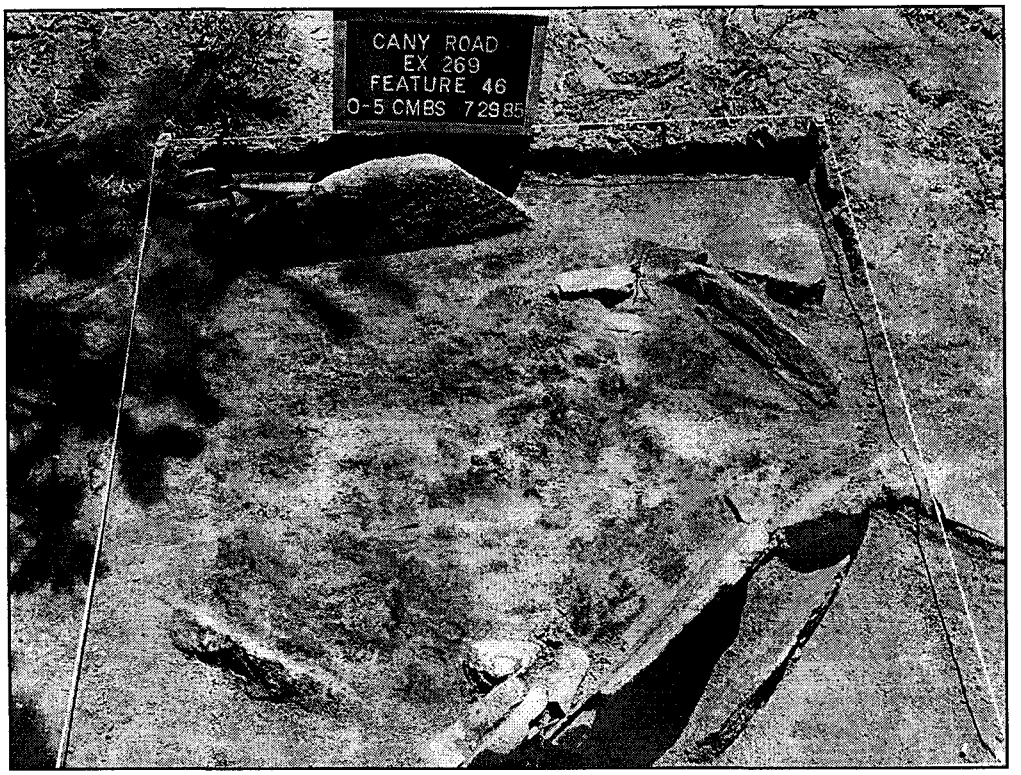


Figure 58. Exposed surface of slab-lined Feature 46, 42SA8500.

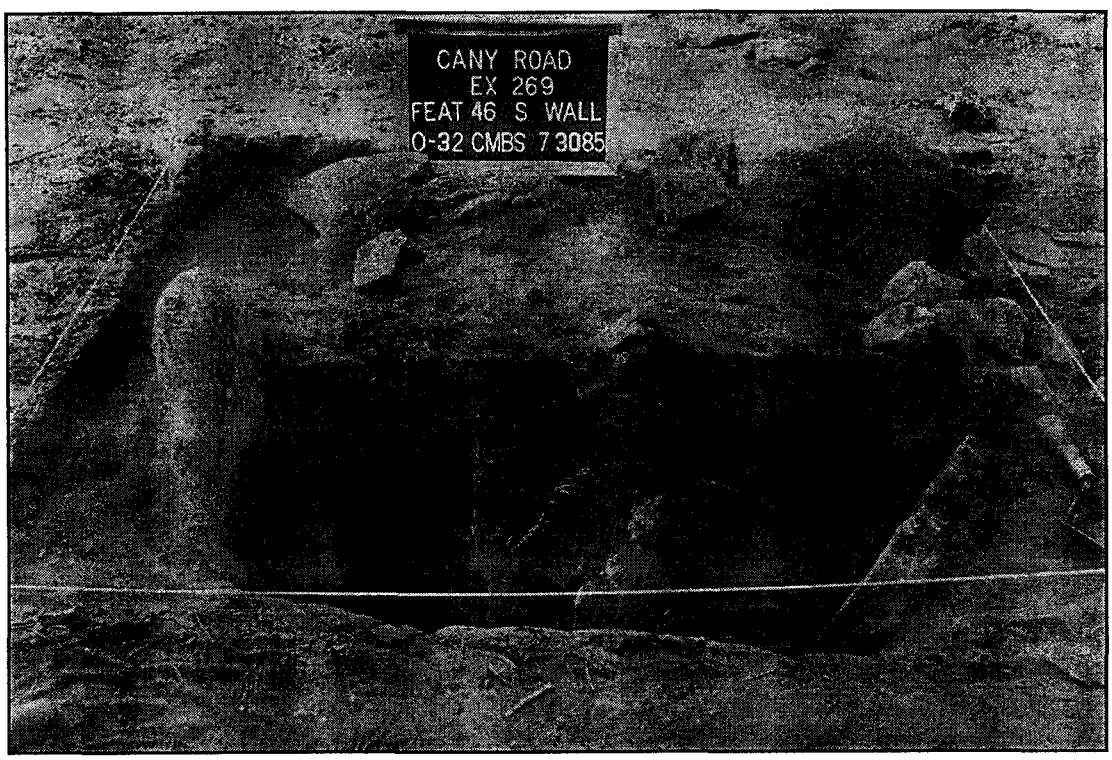


Figure 59. Cross section of slab-lined Feature 46, 42SA8500.

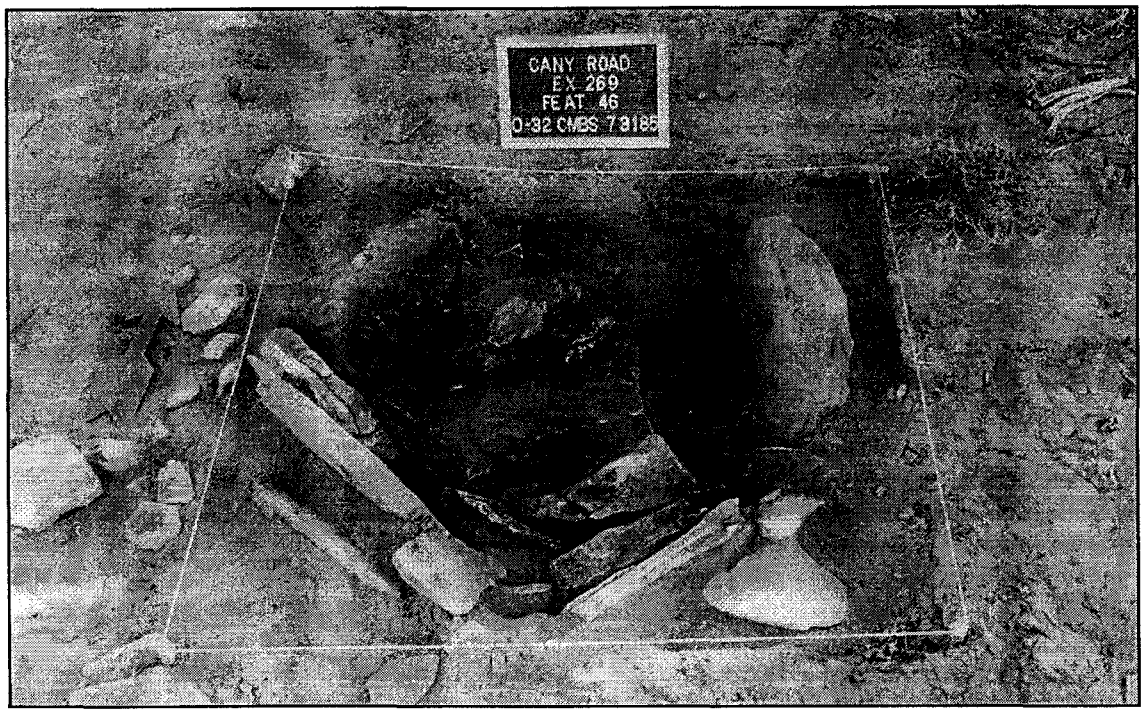


Figure 60. Completed excavation of slab-lined Feature 46, 42SA8500.

Feature 47, 42SA8500

This second slab-lined hearth was excavated at Murphy Trail. It was located 20 to 25 meters southeast of Feature 46. Part of a vertical sandstone slab extending above the ground surface was the initial indication of a subsurface feature. Excavation Unit 271E was subsequently set up at this location revealing construction similar to, but deeper than, Feature 46. The feature was lined with 9 sandstone slabs which varied in thickness from 1 to 5 cm. The sloping outer slabs formed a polygonal plan shape with a contracting cone profile. Outer diameters of the mouth and base were 108 cm and about 70 cm, respectively. The base of each slab rested on bedrock. The interior base of the pit descended 20 cm into the underlying decomposing bedrock. The south half was extracted first, exposing fill 44 cm deep and consisting of four distinct strata. A layer of black sand (5YR 2.5/1) containing abundant charcoal was encountered covering bedrock. Charcoal collected from the lowest stratum yielded a calibrated radiocarbon date of 1095-790 B.C. (Table 16). The lower sections of slabs were blackened, and there was some root disturbance of this level. A fine reddish brown sand deposit (5YR 5/4) with no charcoal covered the lower stratum, possibly indicating a natural fill episode. The next overlying stratum consisted of a reddish brown sand and ashy matrix (5YR 4/3), possibly oxidized, with charcoal flecking. One piece of ground stone, positioned with ground face up, was located in this level, and soil was scraped from its surface for pollen analysis. The uppermost deposit was a fine, loose, light red sand (2.5YR 4/6) with scattered gravels and some light charcoal flecking, probably inblown dune sand. A few flakes were collected from this level. Bulk soil and pollen samples were taken from inside the pit and behind slabs.

Feature 48, 42SA8500

Feature 48 was a hearth located in Excavation Units 287E and 288E. It lay 4 to 5 meters northwest of road stake 74-30 and 7 meters north of the Upheaval Dome Road. The feature's dimensions were 55 cm north-south and 60 cm east-west. Some charcoal chunks and blackened sandstone were observed on the surface. The top of the feature appeared as a generally circular stain with several fire-cracked rocks loosely in position around its periphery. Cross-sectioning revealed a basin-shaped profile with black, charcoal-filled sand that was 10 cm thick. No cultural material was observed within the feature. Charcoal and bulk soil samples were collected.

Feature 49, 42SA8500

Located in Excavation Units 289E and 294E was a basin-shaped hearth, designated Feature 49. The feature lay 10 meters north of Upheaval Dome Road and 10 meters west-northwest of road stake 75-30. The feature's outline was irregular and measured 105 cm EW and 105 cm NS. Dark stained soil and fire-cracked rocks were visible on the ground surface. The fill was 15 cm deep and consisted of a black sand deposit (5YR 2.5/2) with abundant charcoal and scattered fire-cracked rock. No cultural material was located in the feature. Charcoal and bulk soil samples were collected.

Feature 50, 42SA415

A slab-lined hearth, Feature 50, was excavated at Willow Seep site (42SA415) (Figures 61-63). Located 150 meters northeast of Upheaval Dome Road and about 75 meters northeast of Excavation Unit 290E, the feature was first observed as edges of several vertically oriented slabs. Two excavation units, 292E and 297E, were established for feature exploration. At the mouth, the hearth's outer measurements were 80 cm east-west and 90 cm north-south. The pit was constructed of 16 vertical sandstone slabs forming a polygon. The base was formed by four flat, horizontally-laid slabs of varying thickness resulting in a slightly irregular, stepped basal surface. Like the two slab-lined features at Murphy Point, the walls were generally flat and sloped outward. Several slabs were fire-cracked and blackened. Excavation began in the south half and revealed a stratified fill 34 cm thick consisting of four strata. Overlying the basal slabs was a 7- to 20-cm- thick black sand deposit (5YR 2.5/1) with a rich supply of charcoal. Charcoal from this stratum yielded a calibrated radiocarbon date of 410 B.C.-A.D. 15 (Table 16). Covering this was a layer, approximately 10 cm thick, of brown mottled sand (7.5YR 4/4) with a small amount of charcoal. Most of this deposit was covered with a 12-cm-thick layer of dark reddish brown sand (5YR 3/2) with charcoal chunks. However, a small area of the top of the feature fill on the east side was overlain with 7 cm of dark brown sand (7.5YR 5/6) with no charcoal, possibly a non-cultural deposit. The second intermediate stratum contained a significantly smaller

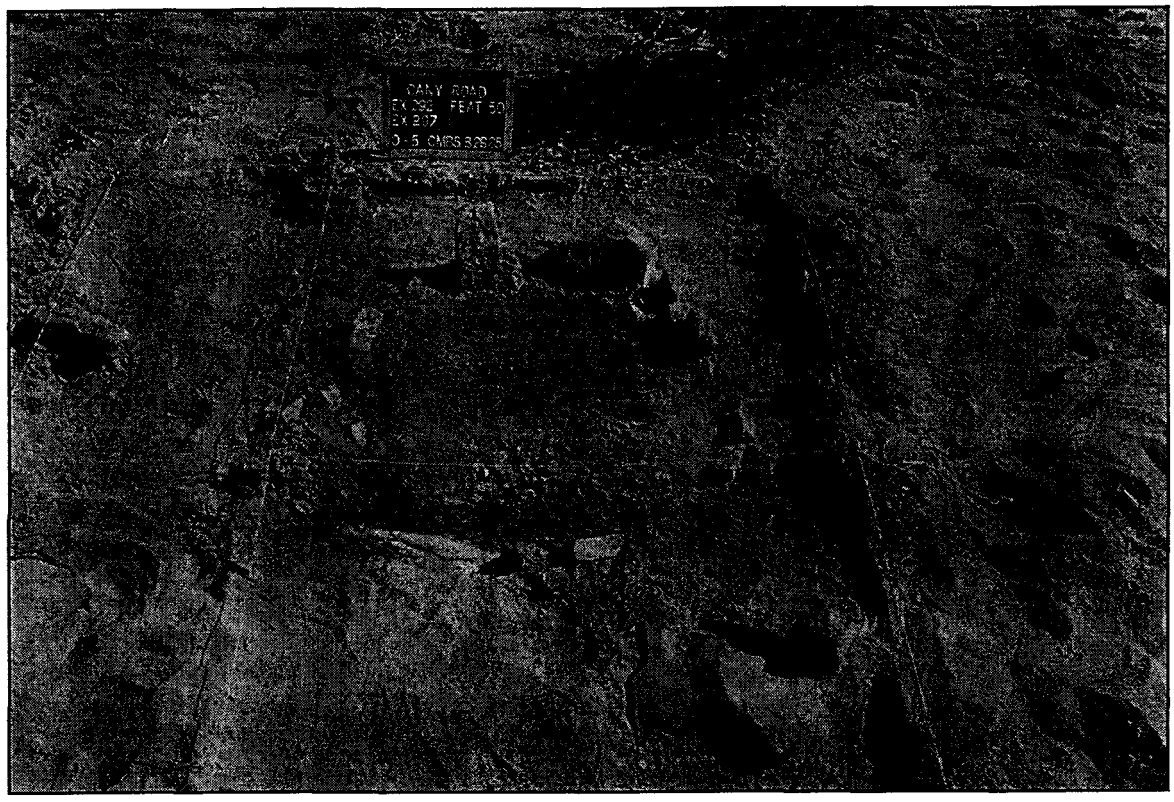


Figure 61. Exposed surface of slab-lined Feature 50, 42SA415.

amount of charcoal than either the overlying or underlying strata, a similar fill sequence to Feature 47. Bulk soil and charcoal samples were taken from all strata. Some samples are mixed, others purely from only one stratum. After full excavation, the slabs were removed and pollen samples collected from behind two of the wall slabs and under the largest of the basal slabs.

Feature 51, 42SA415

Feature 51, a shallow, basin-shaped stain in Excavation Unit 297E, was probably associated with Feature 50. It lay 10 cm south of the southernmost slabs of Feature 50 and at a depth that corresponded with the base of the upper charcoal-rich stratum in the slab-lined hearth. The stain measured 37 cm east-west, 32 cm north-south, and was 1 cm thick, with some scattered mottling continuing for 2 to 3 cm. It was a generally circular area of dark reddish brown sand (5YR 3/2), with charcoal and a few pieces of fire-cracked rock on its surface. No cultural materials were recovered from the feature, and no samples were collected. Although its relationship with Feature 50 is unknown, Feature 51 may have been fill removed from Feature 50.

Feature 53, 42SA8512

Feature 53 was an anomalous grayish-colored stained depression located at 42SA8512. Excavation Unit 272W, containing the feature, was 52 meters west of Upheaval Dome Road and 25-30 meters north-northwest of Centerline Stake 194. The stain was basically circular in plan. It was 43 cm long north-south and 47 cm east-west. The feature was contacted after the first 5 cm of sand was removed from the excavation unit. Sedimentary fill was 15 cm thick, and had the approximation of a basin shape, though the bottom was uneven, probably from some kind of disturbance (e.g., past root activity). Present root activity was also noted. The stain was actually a dark brown, loose sand deposit (7.5YR 4/6), but appeared to have a grayish cast in comparison to the unit fill. The surface of the stain was intersected by "cracks" (linear intrusions) filled with red sand, the surrounding unit fill. Small black specks, possibly

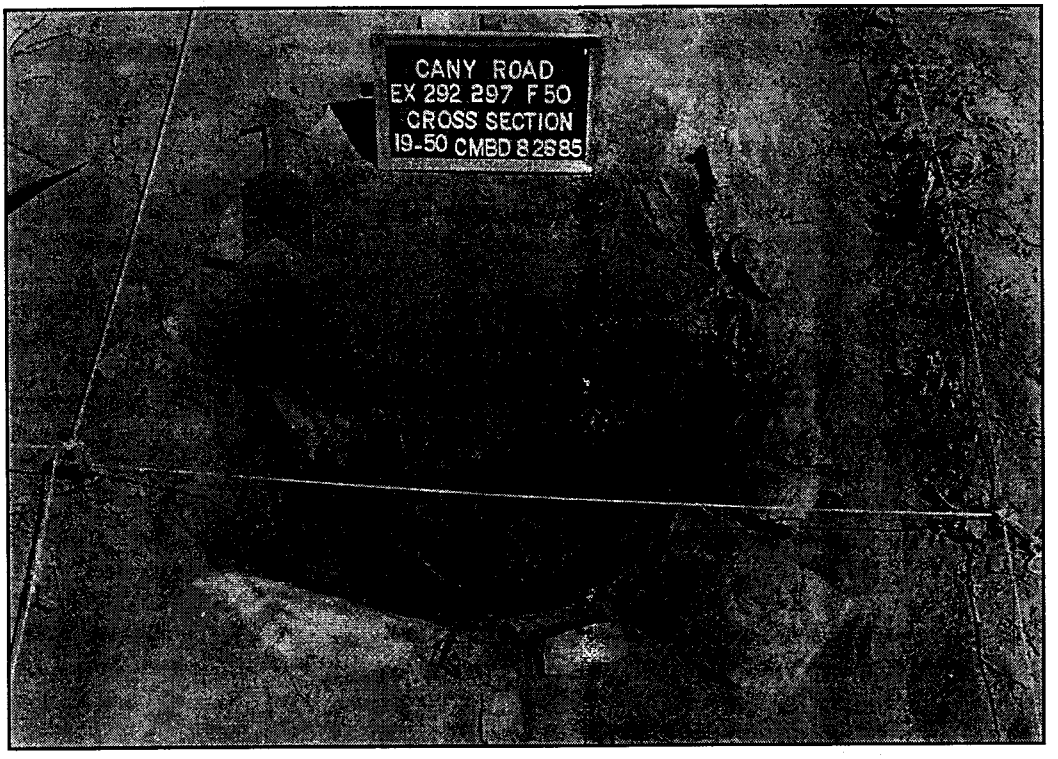


Figure 62. Cross section of slab-lined Feature 50, 42SA415.

Figure 63. Completed excavation of slab-lined Feature 50, 42SA415.

charcoal, were noted in the feature, but were too small to collect. Three artifacts were in association with the feature, two small flakes and a piece of turquoise. Two bulk soil samples were also collected. This was an anomalous feature without a definite cultural association. The unit was situated in a slight depression between dunes; thus, water could have collected on the ground surface, affecting the appearance of the feature.

Feature 54, 42SA8512

Feature 54 was a shallow dark stain located at the block excavation at 42SA8512. In Excavation Units 280W and 281W, the feature measured 60 cm east-west and 40 cm north-south. The outline shape was not recorded. The stain was encountered at 30 cm bs in an area where a relatively high quantity of bone fragments was collected, especially at this depth. The stain had no discernable depth, and bedrock lay from 1 to 3 cm below it. There was no report of charcoal in the feature, and none was collected. One bulk soil sample was collected. Forty-three burnt and unburnt bone fragments were in direct association with the feature.

Feature 55, 42SA8512

A basin-shaped hearth in the block excavation at 42SA8512 was designated as Feature 55. It lay mostly in Excavation Unit 294W and partially in 284W. The feature was identified at 5 cm below the surface as a circular, charcoal-filled stain. The hearth had a 36 cm diameter and 10 cm of fill. The hearth was filled with chunks of charcoal and pieces of unburned wood. No artifacts, rocks, or gravels were present in the feature. Some root disturbance was noted. One bulk soil sample was collected.

Feature 56, 42SA8512

Feature 56 was a basin-shaped ash and charcoal lens in close proximity to bedrock, the last of three features located at the block excavation at 42SA8512. Discovered in Excavation Units 290W and 295W, the stain first appeared as an irregularly shaped circle at 50 cm bd. The lens measured 55 cm from north to south and 57 cm from east to west. The southern and western edges of the feature were more diffuse in outline. One piece of sandstone lay on the eastern border of the stained area. The feature had an irregular cross section with a maximum thickness of 8 cm. Three different deposits were observed. The basal deposit was a brown to dark brown charcoal stained layer (7.5YR 4/4). Bedrock lay 1 to 2 cm below the base of this deposit. This was overlain by a grayish ash and sand layer (5YR 6/1). Within both these deposits were zones of yellowish red silty sand (5YR 5/6) with less concentrated ash and charcoal staining. The contact zones between fill types were uneven and hard to define. The feature contained approximately ten burnt bone fragments and several burnt seeds. Charcoal from the feature yielded a calibrated radiocarbon date of A.D. 1345-1650 (Table 16). One bulk soil sample was collected. Although no flakes were observed in the feature, several were collected from below the feature area.

FLAKED STONE ASSEMBLAGE

INTRODUCTION

Chipped stone tools and debitage represent the greatest portion of the archeological materials collected during the Canyonlands Island-in-the-Sky project. The entire flaked stone assemblage includes 876 bifacial and unifacial tools (698 surface and 178 subsurface), 15 hammerstones, 48 cores and core fragments, and 90,244 pieces of debitage (9,395 subsurface and 80,849 surface). This lithic assemblage is comparatively small with respect to other archeological survey and excavation projects within the American Southwest. For example, the chipped stone tools and subsurface debitage constitute a lithic assemblage that is approximately twice as large as that collected from the excavation of 54 rooms at Broken K Pueblo in east-central Arizona. The Broken K assemblage consists of 473 chipped stone implements and 5,868 pieces of debitage (Longacre 1970). We can gain a somewhat different perspective about the flaked stone assemblage size if we consider that ethnographically documented quantities of lithic raw material for Australian aboriginal males equals approximately 19 kilograms per year. The total flaked assemblage including debitage for this project equals 71.625 kgs, or the equivalent raw material weight used and discarded by one Australian aboriginal male in 3.8 years.

PROJECTILE POINTS

Complete Specimens

In all, 71 complete projectile points were recovered during the pedestrian survey and excavations. These tools were identified as projectile points on the basis of comparisons with traditional projectile point typologies (Black and Metcalf 1986; Heizer and Hester 1978; Holmer 1980, 1986; Holmer and Weder 1980; Thomas and Bierwirth 1983; Tipps 1984; Weder and Sammons-Lohse 1981) and examples of hafted archeological or ethnographical specimens (Fowler and Matley 1979). In addition, these chipped stone implements will be compared to morphometrical data that has been used by archeologists to distinguish between arrow points, dart points, and other tools.

Methodology

Seventeen observations were recorded for each projectile point. These variables include provenience information and field specimen designations, morphological descriptions, composition, metrical attributes, and weight. The provenience information includes an east or west situation within the transect or road right-of-way, a surface mapping point or an excavation unit designation, a unit-specific specimen number, and a surface or subsurface location. The morphological description includes artifact type, general tool type (face), hafting element condition (present/absent), haft or base type, geometric form, and completeness. Specific coded designations for each of these morphological and compositional variables are included in Appendix C.

Metrical attributes for hafted bifaces—particularly corner-notched, side-notched, or side- and basal-notched projectile points—include: (1) maximum length (proximal-distal); (2) maximum axial length (central longitudinal axis); (3) haft length; (4) maximum width (perpendicular to longitudinal axis); (5) base width (proximal width); (6) neck width; and (7) maximum thickness. Metrical attributes are described schematically in Figure 64. Measurements for unhafted bifaces or bifaces that do not exhibit notches, stems, or pronounced proximal elements include: (1) maximum length (proximal-distal); (2) maximum width (perpendicular to longitudinal axis); (3) maximum thickness; and (4) weight. All metrical measurements were made to the nearest millimeter using sliding vernier calipers. Weight was measured with a Dial-O-Gram (2,610 gram) laboratory balance. All data were entered initially on laboratory record sheets and was then transferred to Ashton-Tate's dBase III+ database management computer program. Data editing, sorting, and initial counting were carried out using this computer program. New subfiles may be created in dBase III+ and transformed into files suitable for importation into statistical programs for further analysis.

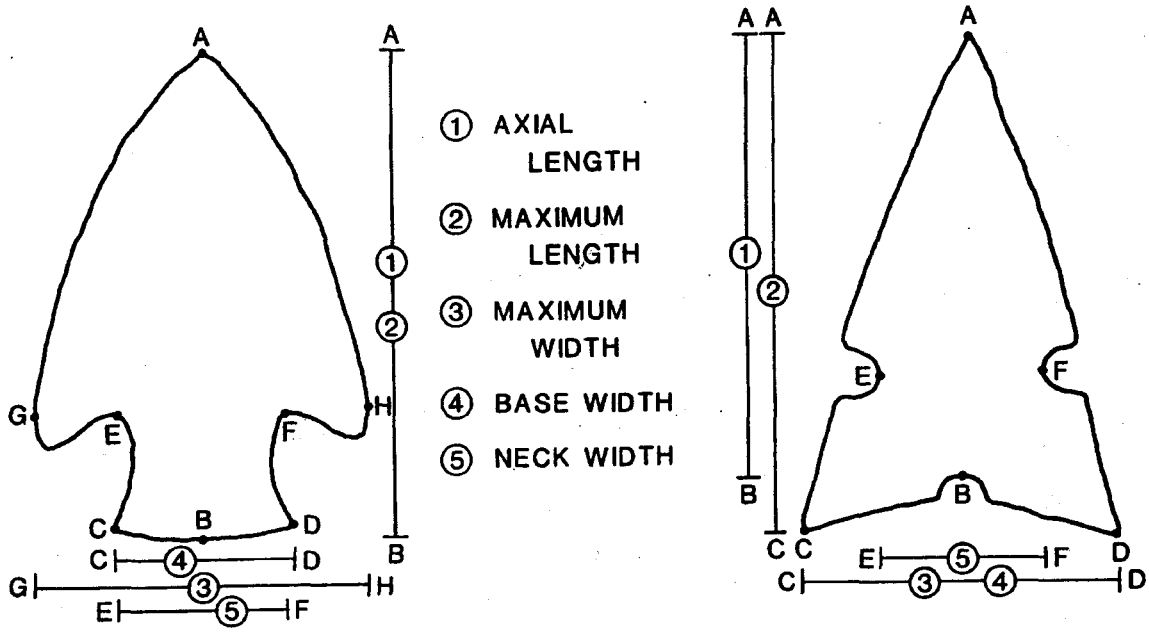


Figure 64. Metrical attributes of projectile points.

Description and Analysis

Summary descriptive statistics for the complete projectile points are provided in Table 19. These implements range in maximum length from 12 mm to 67 mm and in weight from 0.15 grams to 12.70 grams. Eighty-seven percent of these chipped stone implements exhibit lengths equal to or less than 34 mm and weights equal to or less than 1.60 grams.

These projectile points were also divided into subgroups considered to be similar to traditional types used in the Colorado Plateau and Great Basin regions. These types include Desert Side-notched, Bull Creek, Elko Corner-notched, and Cottonwood projectile points (e.g., Holmer and Weder 1980) (Figures 65-75). Tabular summaries of descriptive statistics for these projectile point subgroups are provided in Tables 20-28.

Although archeologists working in the Great Basin and the American Southwest have frequently used projectile point types as "index fossils" within a cultural-historical framework, this practice is questionable. Holmer (1986) examined the formal characteristics and the spatial and temporal distribution of 10 general forms of projectile points in the Intermountain West. These generalized forms were utilized to create a general chronological sequence for the entire region. Eight projectile point forms do not appear to ".. exhibit temporal coincidence in the entire Intermountain West" (Holmer 1986:109). Furthermore, these forms do not exhibit continuous geographical distribution in the archeological record for this vast region. And, dates for the appearance or disappearance of these generalized projectile point forms vary across the various subregions.

For example, Holmer (1986:101) states that Elko Corner-notched or Elko Eared points occur in the eastern Intermountain West (e.g., Hogup Cave) between 4200-3000 B.C. and from 1400 B.C. to A.D. 200; on the other hand, the same point series occurs in the western portion of the region (e.g., Gatecliff Shelter and Hidden Cave) between 1300 B.C. and A.D. 700. Holmer's (1978, 1986:102) discriminant analysis revealed no statistical difference between these two geographically distinct groups of Elko series projectile points. These conclusions suggest that archeologists cannot rely on such traditional projectile point taxonomies for assigning "absolute" dates to archeological sites, specific strata, or features in the absence of radiometric dates.

Small side-notched projectile points have also been assigned culture-historical significance by archeologists working in the Intermountain West. These implements have generally been referred to as Desert Side-notched points (Baumhoff 1957). Holmer and Weder (1980:60) point out that these projectile points are frequently found in association with Shoshoni ceramics. They (1980:60) state, "The conclusion is that the occurrence of Desert Side-notched points does not result from Fremont occupations, but indicates post-Fremont (Shoshoni) use of the area after approximately A.D. 1150." Holmer (1986:107), however, suggests that there is morphological variation within this general group, that patterns vary both spatially and temporally. Small side-notched projectile points occur between A.D. 800-1200 in association with Fremont ceramics, and between A.D. 1200 and A.D. 1700 with Numic ceramics (Holmer and Weder 1980:60).

A number of Desert Side-notched points, as well as small concave-based triangular points, were hafted to arrows collected among the Numa by John Wesley Powell in the Great Basin and the Colorado Plateau between 1867 and 1880. A tabular summary of the dimensions of 167 arrows collected from the Kaibab Southern Paiute, the Moapa Southern Paiute, the Southern Paiute, the Bear Lake Shoshoni, and the Deep Creek Gosiute is presented in Fowler and Matley (1979:87-91, Appendix: Table 1). Measurements of maximum length, width, and thickness of 88 chipped stone points were subjected to statistical analysis. The mean maximum length, width, and thickness equal 25.61 mm, 13.60 mm, and 3.60 mm, respectively. Chipped stone arrow points ranged in maximum length from 14 mm to 41 mm, in maximum width from 9 mm to 21 mm, and in maximum thickness from 2 mm to 7 mm. Fowler and Matley (1979) do not provide data regarding chipped stone arrow point weights.

The seventy-one complete chipped stone projectile points (Table 19) collected during survey and excavation in Canyonlands vary in width and thickness from the historic Numa hafted arrow points. A series of t-tests for independent means reveals that the Canyonland sample exhibits similar mean maximum length ($t=0.1868$; $p=0.8522$), but different mean maximum width ($t=1.8198$; $p=0.0719$) and mean maximum thickness ($t=-2.7597$; $p=0.0066$).

In summary, more than 87 percent of the complete projectile points recovered can be tentatively classed as arrowpoints. Recent studies of projectile points conducted by Flenniken and Raymond (1986), Flenniken and Frison (1968), Holmer (1986), and Wilke (1989) have emphasized that chipped stone projectile points may undergo marked morphological change during their use life as a function of use, attrition, breakage, and resharpening. Flenniken and Wilke (1989:151) state that archeologists have frequently assumed that "Once manufactured, flaked stone dart point forms were static index fossils and underwent little or no formal change in the basal or haft area of the point where typologically sensitive attributes occur ...." These authors (1989:152) also point out that dart or atlatl points in the Great Basin region were subject to a number of different forms of breakage, damage, and attrition. As a result, recycled points"... always change form, and they frequently key out as different types using classification keys commonly in use (Holmer 1978; D.H. Thomas 1981)." Flenniken and Wilke (1989:154-155, Figures 1 and 2) provide illustrations of potential patterns of morphological and typological change that might produce the Gypsum Cave, Little Lake, and/or Humbolt series from an initial Elko series dart point.

There are several projectile points in the Canyonlands collection that appear to have been broken during use and either modified into other tools or resharpened while still hafted in an arrow or dart shaft (Figure 74, g-i). For example, specimens a-e in Figure 75 exhibit both low maximum and axial lengths and somewhat irregular forms. The distal portions of the blade were probably broken and were then retouched while still hafted in the arrow shaft or foreshaft. Such a breakage and modification sequence is illustrated in Figure 73a, b, for Desert Side-notched projectile points.

The third item in Figure 73d probably represents a Cottonwood-like projectile point that fractured laterally across the blade and was then resharpened in the haft. Similarly, a perforator manufactured from an Elko series dart point is illustrated in Figure 73e.

Incomplete Projectile Points

Two hundred forty-one proximal fragments of projectile points are statistically described in Table 28. These fragments appear to represent larger projectile points than the sample of complete points described in Table 19. The point bases exhibit a greater mean width,

thickness, and weight than the complete projectile points. A series of t-tests for two sample means reveals that these two groups of projectile points are significantly different with respect to mean width (t=-6.8334; p=0.00), thickness (t=-6.7526; p=0.00), and weight (t=-4.7135; p=0.00).

Table 19. Descriptive statistics for complete projectile points.

	Max. length (mm)	Axial length (mm)	Haft length (mm)	Max. width (mm)	Base width (mm)	Neck width (mm)	Max. thick. (mm)	Weight (g)
Mean	25.89	24.39	6.78	14.77	12.45	7.91	3.07	1.37
s.d.'	11.50	11.72	2.38	4.95	4.34	2.65	1.36	2.35
C.V.	0.44	0.48	0.35	0.34	0.35	0.33	0.44	1.72
Min.	12.00	10.00	1.20	8.50	2.50	4.50	1.60	0.15
Maxi.	67.00	66.00	14.55	32.00	31.00	15.00	10.70	12.70
Range	55.00	56.00	13.35	23.50	28.50	10.50	9.10	12.55

s.d.' – sample standard deviation; C.V. – coefficient of variation
(N = 71)

Table 20. Descriptive statistics for complete Desert Side-notched projectile points.

	Max. length (mm)	Axial length (mm)	Haft length (mm)	Max. width (mm)	Base width (mm)	Neck width (mm)	Max. thick. (mm)	Weight (g)
Mean	21.64	19.04	6.63	12.67	12.18	7.46	2.44	0.51
s.d.'	6.42	6.18	1.71	1.92	2.30	2.07	0.49	0.29
C.V.	0.30	0.32	0.26	0.15	0.19	0.28	0.20	0.57
Min.	12.00	10.00	2.00	9.20	6.80	4.80	1.60	0.15
Max.	33.50	29.50	9.50	16.90	16.90	12.35	4.00	1.60
Range	21.50	19.50	7.50	7.70	10.10	7.55	2.40	1.45

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 28)

Table 21. Descriptive statistics for complete Cottonwood projectile points.

	Max. length (mm)	Axial length (mm)	Haft length (mm)	Max. width (mm)	Base width (mm)	Neck width (mm)	Max. thick. (mm)	Weight (g)
Mean	22.89	22.01	—	15.07	14.54	—	2.73	0.71
s.d.'	3.73	3.78	—	3.62	3.80	—	0.52	0.23
C.V.	0.16	0.17	—	0.24	0.26	—	0.19	0.33
Min.	14.55	14.30	—	10.10	9.80	—	1.70	0.25
Max.	29.15	28.00	—	27.00	27.00	—	3.50	1.20
Range	24.00	13.70	—	18.75	17.20	—	1.80	0.95

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 25)

Table 22. Descriptive statistics for complete Rose Spring projectile points.

	Max. length (mm)	Axial length (mm)	Haft length (mm)	Max. width (mm)	Base width (mm)	Neck width (mm)	Max. thick. (mm)	Weight (g)
Mean	27.94	27.75	5.81	13.97	6.14	5.95	3.54	1.15
s.d.'	5.65	5.56	0.79	3.23	2.08	1.69	0.78	0.54
C.V.	0.20	0.20	0.14	0.23	0.34	0.28	0.22	0.47
Min.	22.00	22.00	4.50	8.85	2.50	4.50	2.70	0.50
Max.	36.00	35.50	6.60	18.10	8.90	8.80	4.55	1.80
Range	14.00	13.50	2.10	9.25	6.40	4.30	1.85	1.30

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 6)

Table 23. Descriptive statistics for complete Bull Creek projectile points.

	Max. length (mm)	Axial length (mm)	Haft length (mm)	Max. width (mm)	Base width (mm)	Neck width (mm)	Max. thick. (mm)	Weight (g)
Mean	41.80	39.42	—	13.90	13.40	—	3.52	1.80
s.d.'	1.70	2.37	—	1.84	2.55	—	0.39	0.42
C.V.	0.04	0.06	—	0.13	0.19	—	0.11	0.24
Min.	40.60	37.75	—	12.60	11.60	—	3.25	1.50
Max.	43.00	41.10	—	15.20	15.20	—	3.80	2.10
Range	2.40	3.35	—	2.60	3.60	—	0.55	0.60

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 2)

Table 24. Descriptive statistics for complete and incomplete Elko Series projectile points.

	Max. length (mm)	Axial length (mm)	Haft length (mm)	Max. width (mm)	Base width (mm)	Neck width (mm)	Max. thick. (mm)	Weight (g)
Mean	28.81	—	10.24	27.52	17.46	12.42	5.80	4.48
s.d.'	15.61	—	2.30	5.57	6.02	1.81	2.22	2.18
C.V.	0.54	—	0.22	0.20	0.34	0.15	0.38	0.49
Min.	15.00	—	6.90	19.85	10.70	10.70	4.10	1.70
Max.	65.85	—	13.00	35.70	25.20	15.60	11.00	7.90
Range	48.85	—	6.10	15.85	14.50	4.90	6.90	6.20

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 8)

Table 25. Descriptive statistics for incomplete Gatecliff Contracting-stem projectile points.

	Max. length (mm)	Axial length (mm)	Haft length (mm)	Max. width (mm)	Base width (mm)	Neck width (mm)	Max. thick. (mm)	Weight (g)
Mean	38.52	—	—	30.65	—	19.20	6.69	5.87
s.d.'	25.69	—	—	4.55	—	3.86	1.58	2.48
C.V.	0.67	—	—	0.15	—	0.20	0.24	0.42
Min.	24.30	—	—	24.20	—	14.80	4.65	2.50
Max.	77.00	—	—	34.90	—	22.00	8.50	8.10
Range	52.70	—	—	10.70	—	7.20	3.85	5.60

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 4)

Table 26. Descriptive statistics for complete and incomplete Sudden Side-notched projectile points.

	Max. length (mm)	Axial length (mm)	Haft length (mm)	Max. width (mm)	Base width (mm)	Neck width (mm)	Max. thick. (mm)	Weight (g)
Mean	37.03	—	9.35	21.53	19.77	14.20	6.10	4.67
s.d.'	16.87	—	1.43	1.36	0.84	0.66	1.35	0.97
C.V.	0.45	—	0.15	0.06	0.04	0.05	0.22	0.21
Min.	23.70	—	8.45	20.60	18.80	13.50	4.70	3.60
Max.	56.00	—	11.00	23.10	20.30	14.80	7.40	5.50
Range	32.30	—	2.55	2.50	1.50	1.30	2.70	1.90

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 3)

Table 27. Descriptive statistics for complete and incomplete Northern Side-notched projectile points.

	Max. length (mm)	Axial length (mm)	Haft length (mm)	Max. width (mm)	Base width (mm)	Neck width (mm)	Max. thick. (mm)	Weight (g)
Mean	27.83	—	12.42	26.43	24.50	14.70	4.58	3.15
s.d.[1]	26.13	—	3.01	3.96	9.19	2.36	0.35	3.07
C.V.	0.94	—	0.24	0.15	0.37	0.16	0.08	0.98
Min.	12.50	—	10.30	24.00	18.00	12.20	4.20	1.35
Max.	58.00	—	14.55	31.00	31.00	16.90	4.90	6.70
Range	45.50	—	4.25	7.00	13.00	4.70	0.70	5.35

s.d.[1] – sample standard deviation; C.V. – coefficient of variation.
(N = 3)

Table 28. Descriptive statistics for incomplete projectile points–proximal fragments.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	22.68	21.06	4.72	3.51
s.d.[1]	11.66	11.00	2.84	5.55
C.V.	0.51	0.52	0.60	1.58
Min.	5.15	7.30	1.60	0.10
Max.	77.00	73.50	16.25	45.30
Range	71.85	66.20	14.65	42.25

s.d.[1] – sample standard deviation; C.V. – coefficient of variation.
(N = 241)

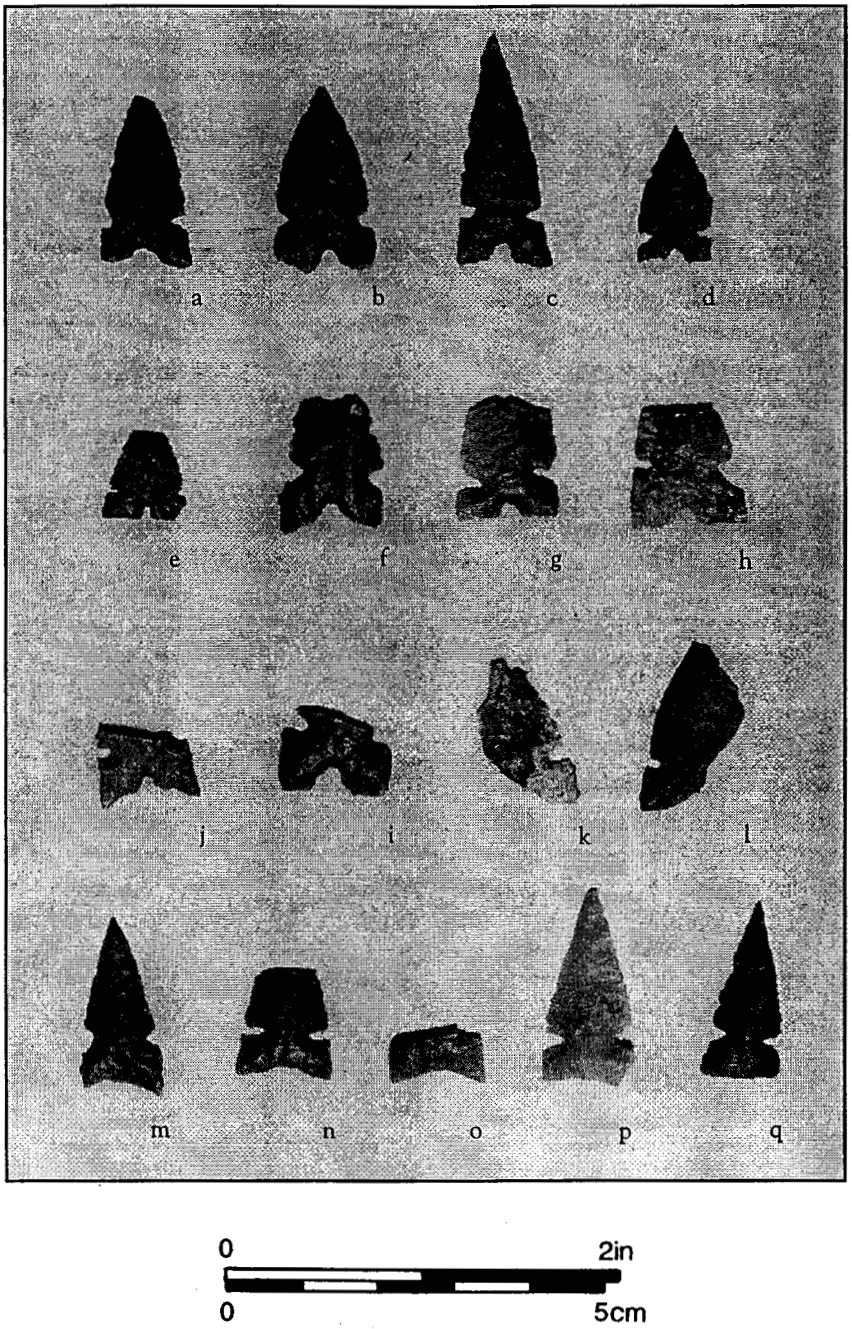


Figure 65. Complete and incomplete Desert Side-notched projectile points.

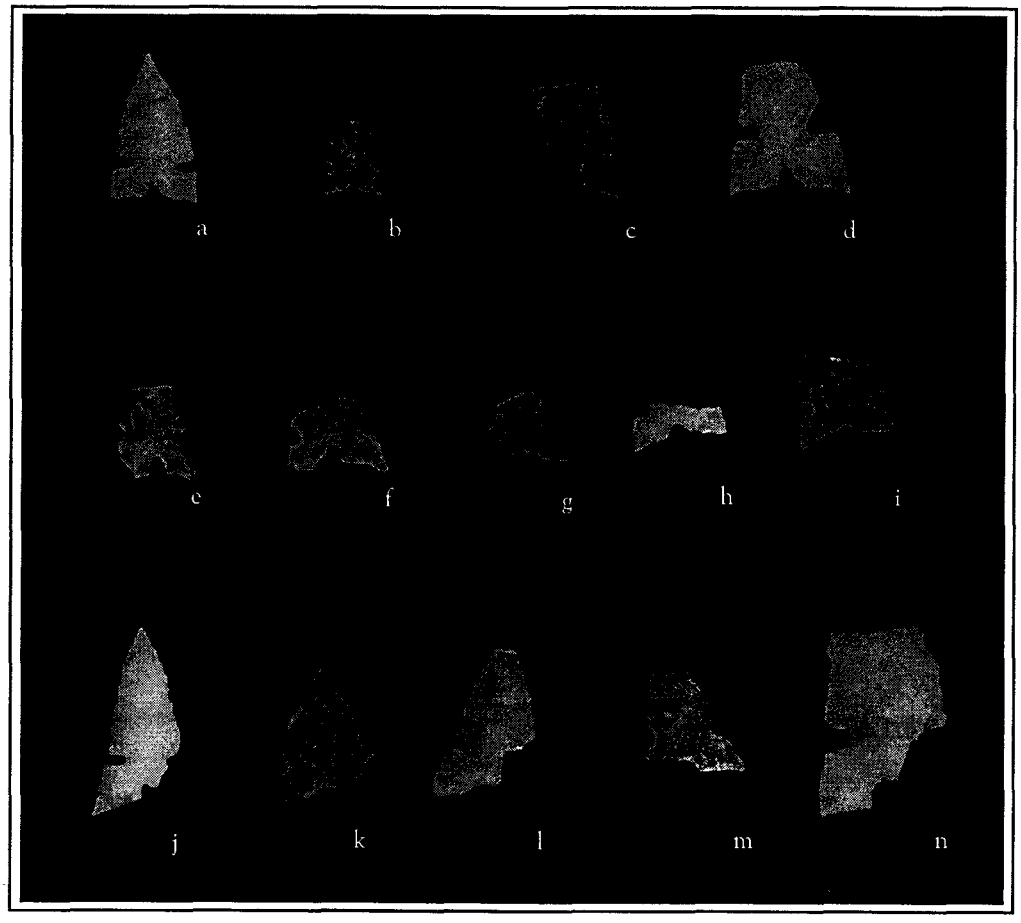


Figure 66. Complete and incomplete Desert Side-notched projectile points.

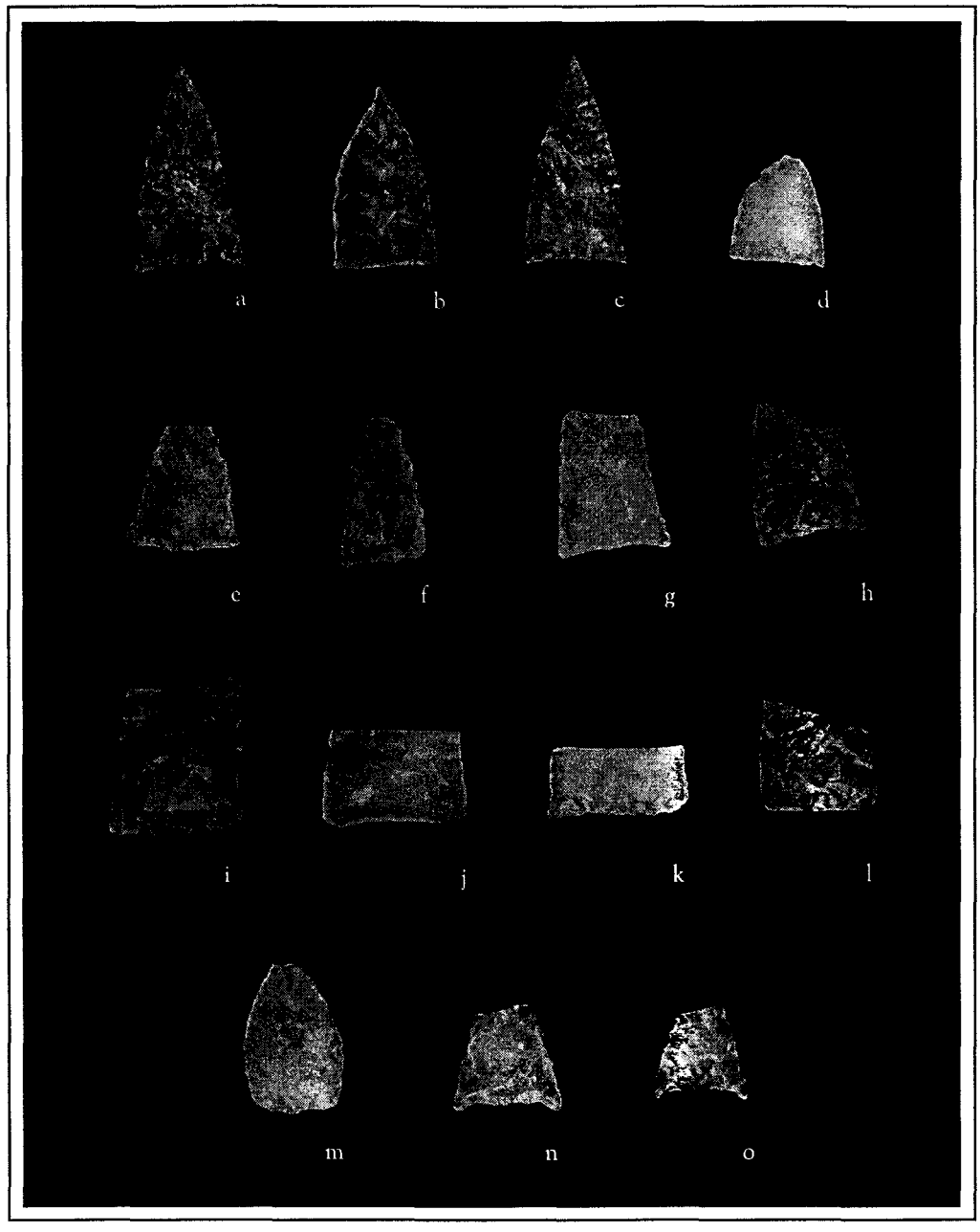


Figure 67. Complete and incomplete Cottonwood projectile points.

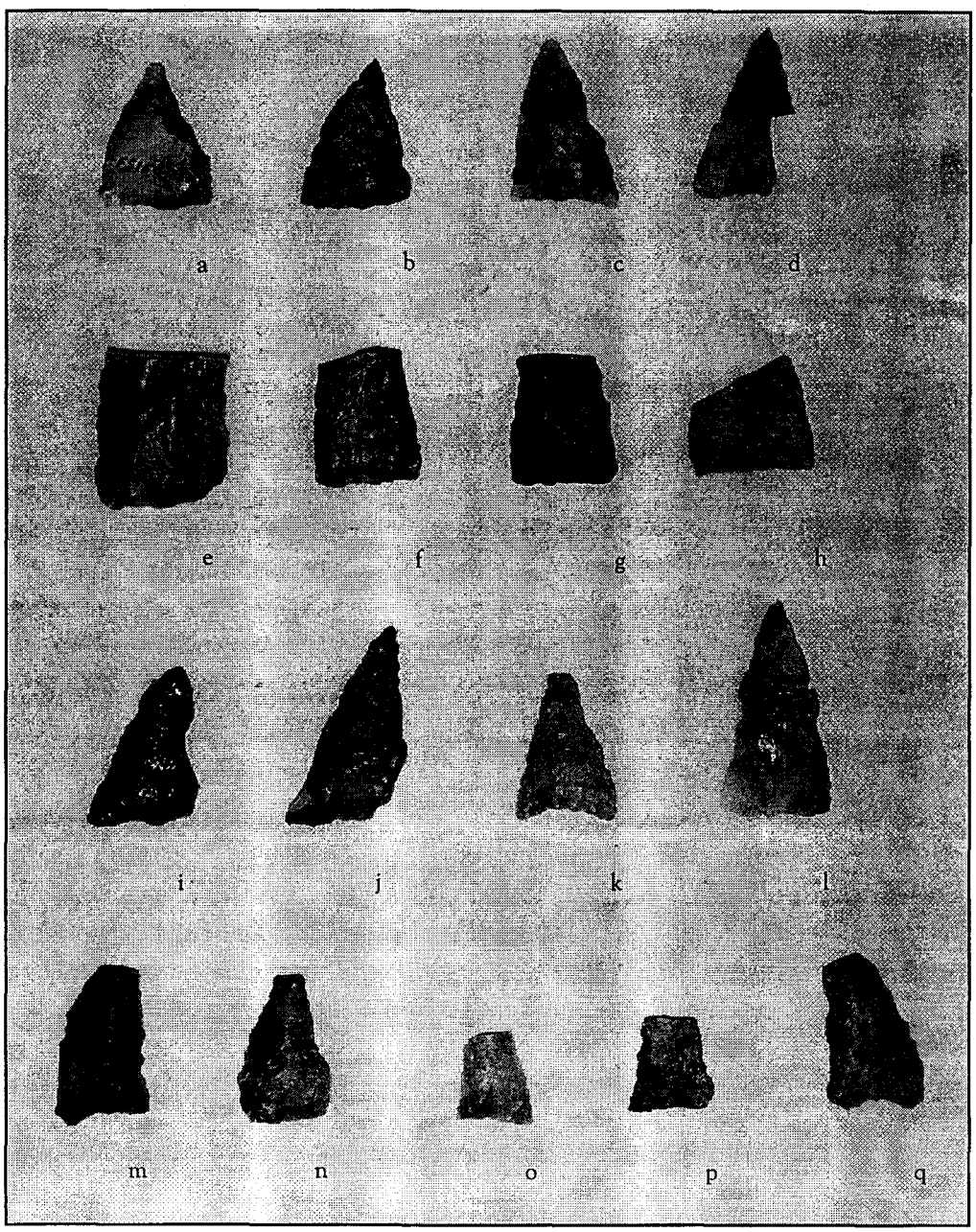


Figure 68. Complete and incomplete Cottonwood projectile points.

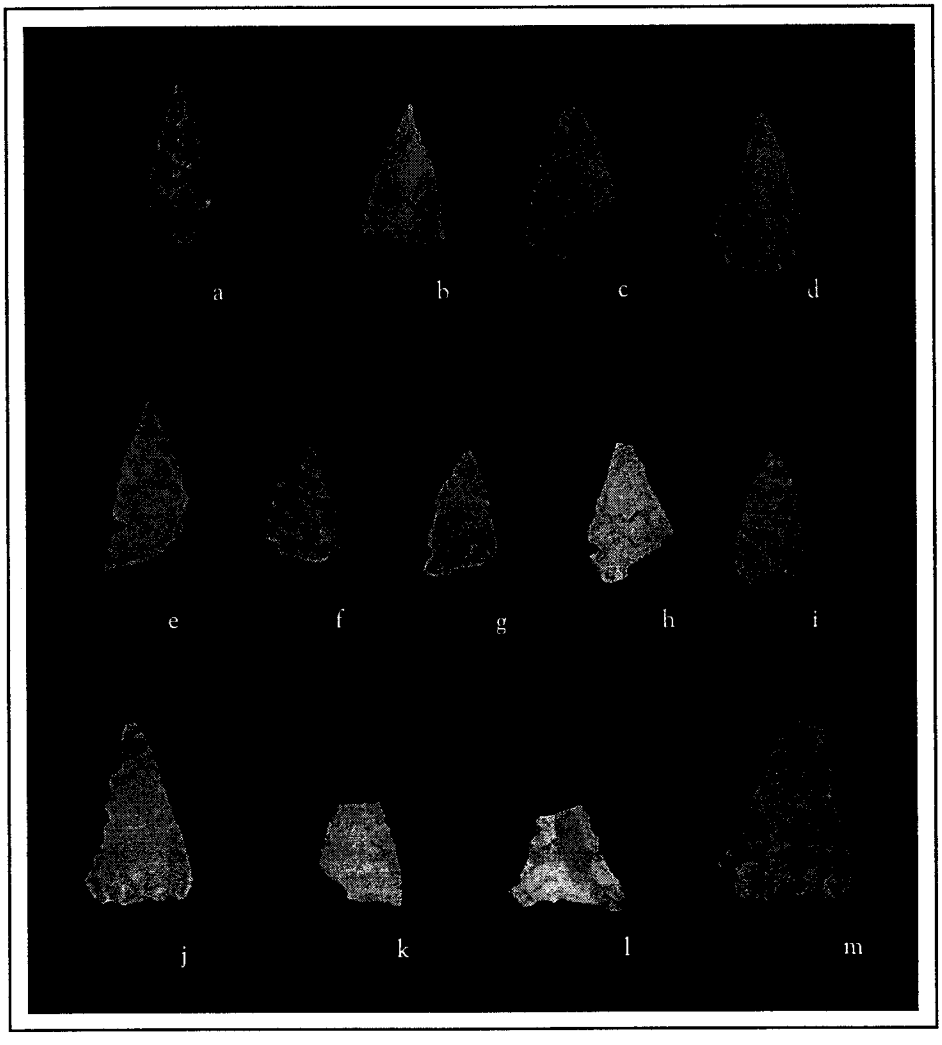


Figure 69. Miscellaneous complete and incomplete projectile points.

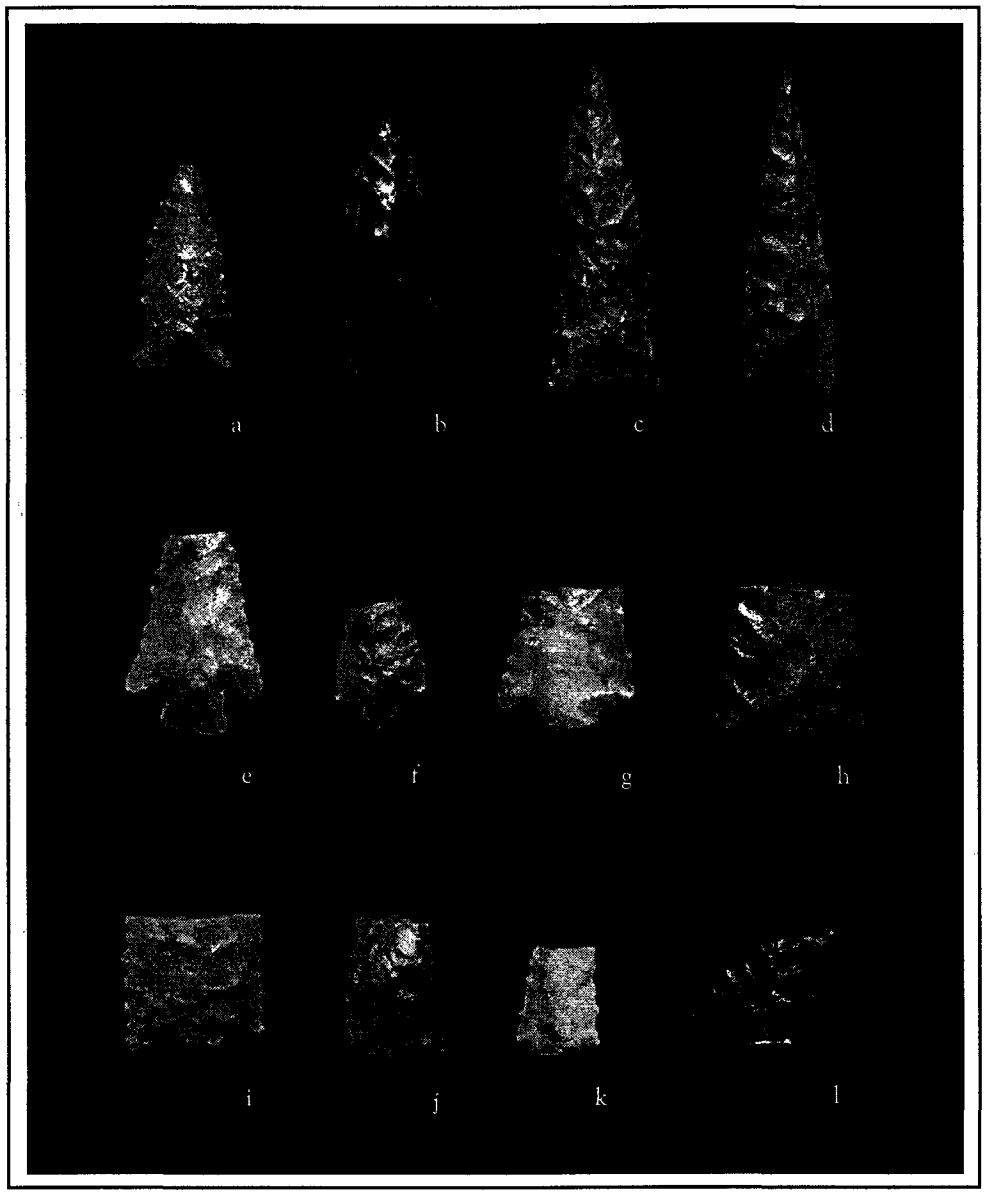


Figure 70. Miscellaneous complete and incomplete projectile points.

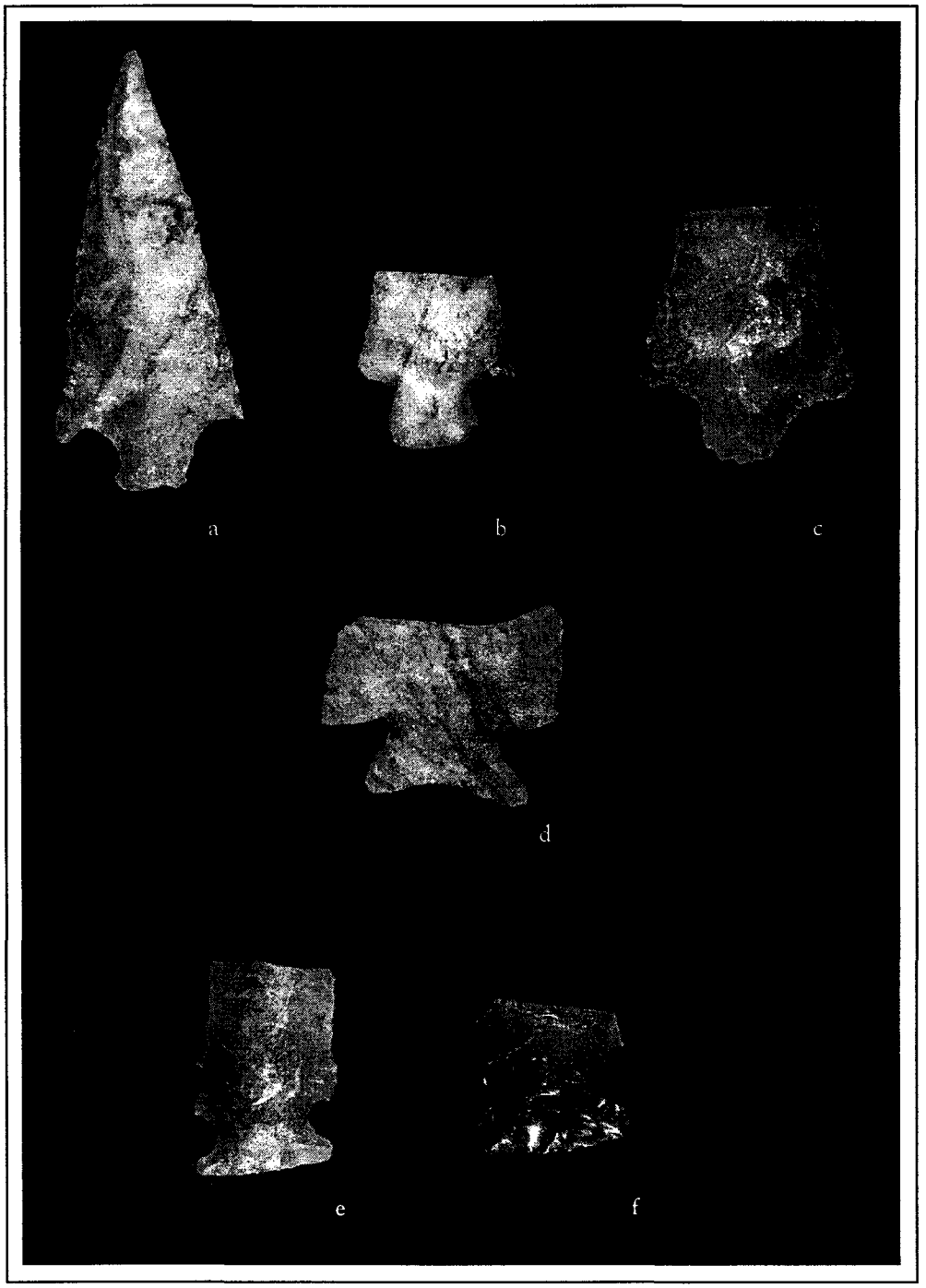


Figure 71. Complete and incomplete stemmed and Elko Series projectile points.

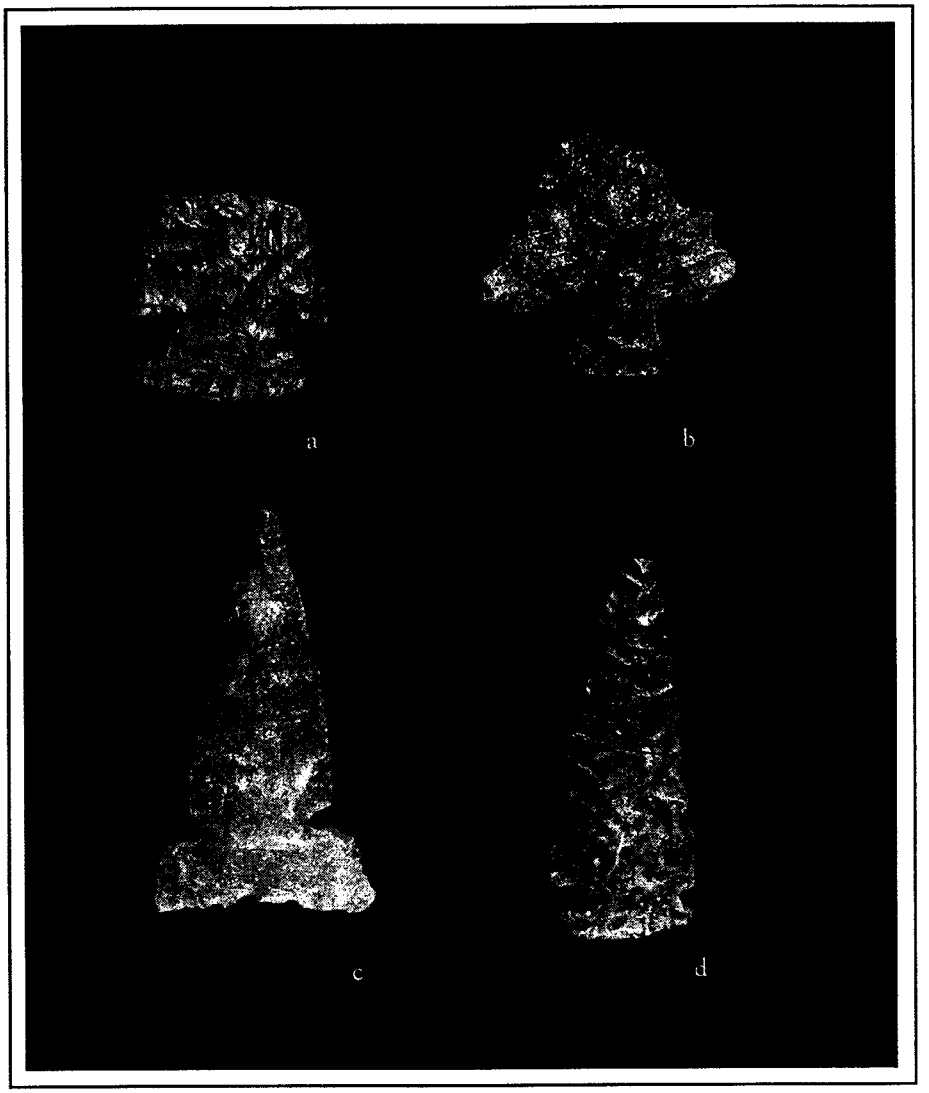


Figure 72. Complete and incomplete corner- and side-notched projectile points.

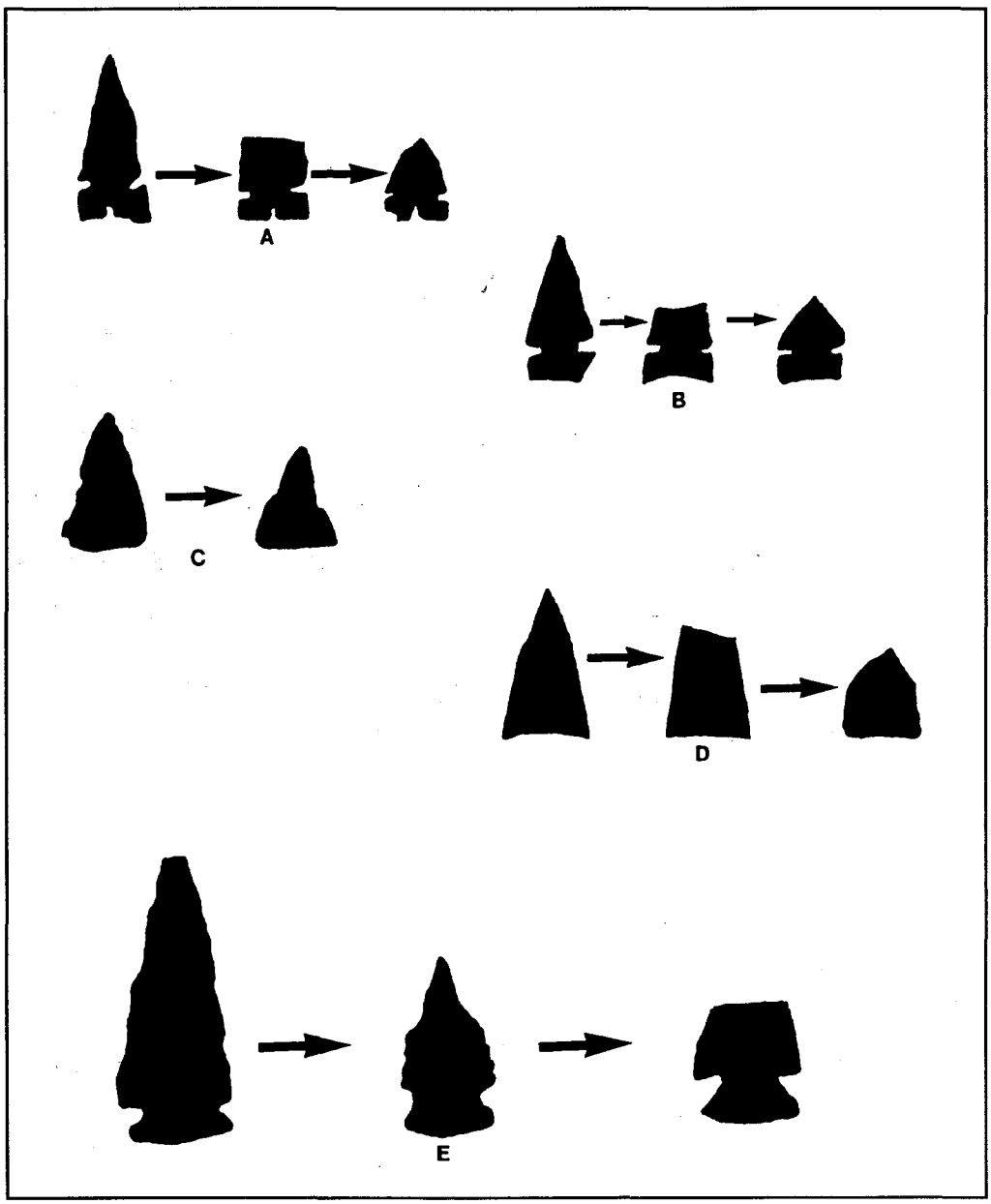


Figure 73. Suggested breakage and resharpening sequences for projectile points based on actual specimens.

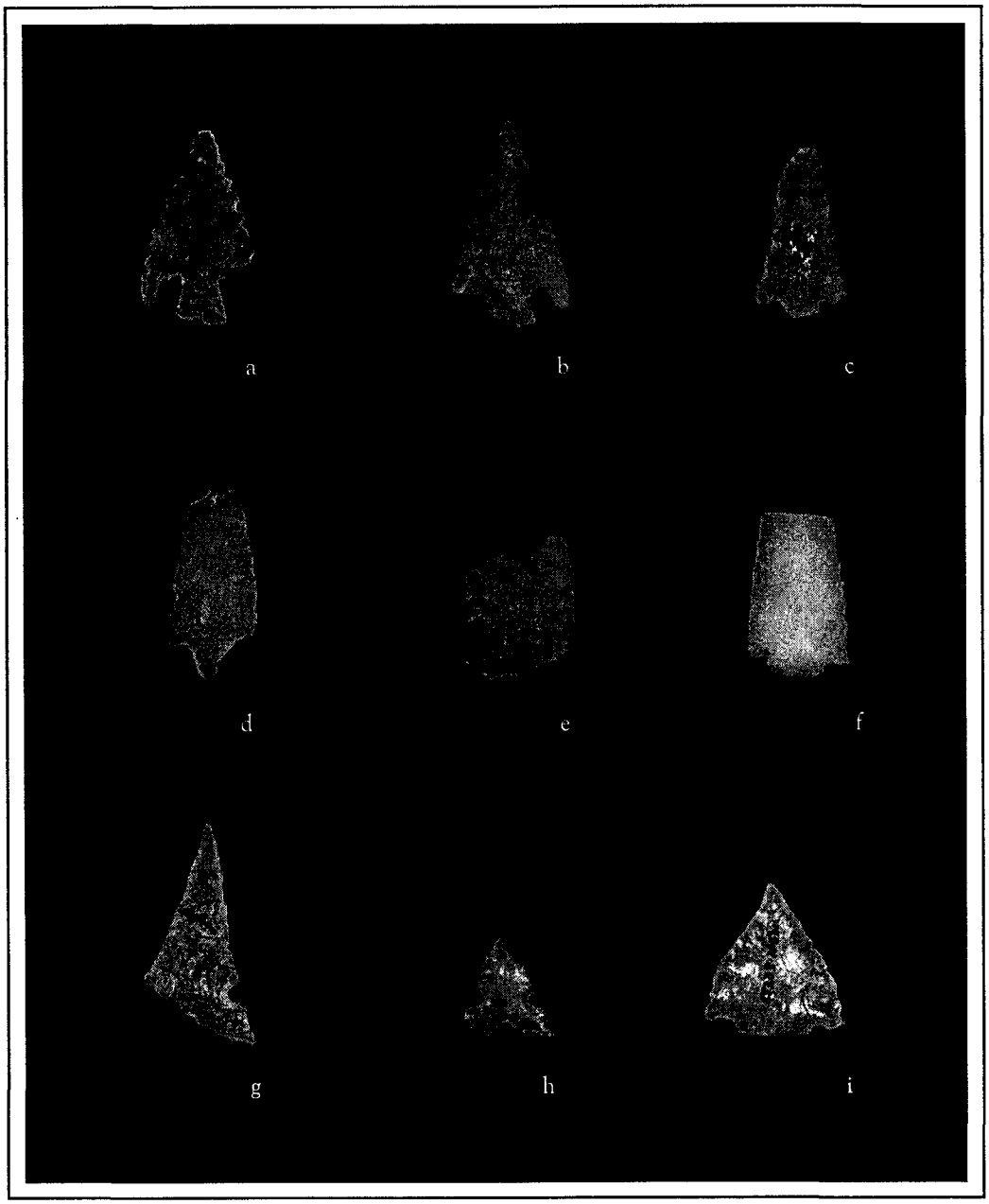


Figure 74. Miscellaneous projectile points including resharpened points (specimans g, h, i).

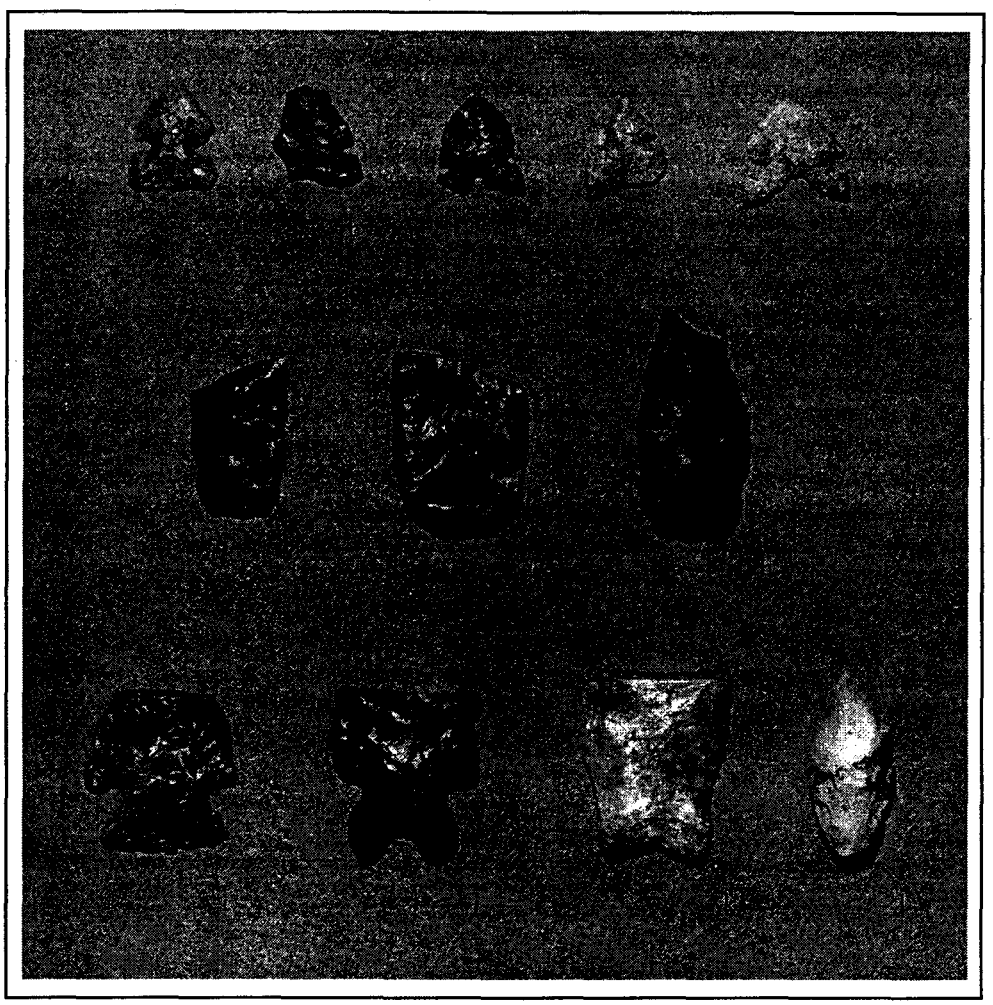


Figure 75. Miscellaneous projectile points including resharpened points (specimens a-e).

BIFACES

Twenty-nine complete bifacially-flaked stone implements were recovered. These bifaces are quite variable in size and weight. Two bifacially-flaked implements recovered from the Neck site (42SA8502) exhibit maximum lengths equal to 155 and 63 mm, maximum widths equal to 68.40 and 66.90 mm, maximum thicknesses equal to 13.30 and 19.70 mm, and weights equal to 145.50 and 214.70 grams, respectively (Figure 76; Table 29). Intermediate size bifaces range in length from 44.10 to 98.50 mm and vary in maximum thickness from 5.90 to 7.75 mm (Figure 77; Table 30).

INCOMPLETE MISCELLANEOUS BIFACES

Four hundred four incomplete bifaces were not assigned type designations on the basis of morphological attributes, e.g., shape or haft or base type. All specimens included in this category were assigned to an "indeterminate" base type category. These biface fragments vary in maximum length from 4.5 to 98.7 mm, in width from 4.5 to 75 mm, and in thickness from less than 0.5 mm to 28.4 mm. The mean maximum length-to-maximum width ratio equals 3.54. Weights range from 0.05 grams to 130.2 grams. More than 72 percent of the incomplete, indeterminate bifaces weigh less than 7.28 grams. A series of regression analyses revealed that there is little relationship between maximum length-to-maximum width ratios, maximum length, maximum width, or thickness and weight. These analyses indicate that the bifaces exhibit considerable variation in size and morphology (Figure 78; Tables 31 and 32). Approximately 55 percent of these bifaces were produced from cherts, 42 percent from chalcedonies, and less than one percent from either quartzite or obsidian. More than 91 percent lacked cortex.

UNIFACES

Sixty-seven unifacial implements were divided into two general categories—distally-modified tools and laterally-modified tools. Distally-modified tools correspond to the general category of endscrapers (Figures 79 and 80; Tables 33 and 34). Fourteen distally-modified tools are complete, and nine are incomplete. Complete specimens range in maximum length from 27.80 to 74.10 mm. Commonly, such tools are produced by steeply retouching the distal edge of a relatively thick, expanding flake. Ethnographic specimens collected from Eskimo and Plains Indian groups were frequently hafted in wood, antler, bone, or ivory handles (Hayden 1979; Nissen and Dittemore 1974). Such tools were used for scraping and softening animal hides. O'Connell (1974), on the other hand, provides us with an interesting discussion of similar chipped stone implements used by the Alyawara in Central Australia. Although the chipped stone tools made and used by these aborigines are steeply and distally retouched flakes with plano-convex cross sections, they were women's knives and were used as scoops or spoons for eating baked or roasted tubers. O'Connell (1974:194) states that these ".. yilugwa in prehistoric sites in central Australia may be taken as an indication of the consumption of roots and tubers, as well as light-duty woodworking". Several specimens exhibit contracting "stems" or proximal ends that probably indicate that they were fitted into handles (Figures 79d; 80b,d,f).

Forty-four laterally-modified implements comprise this category. These tools have been traditionally referred to as sidescrapers, although their function is unknown. Thirty-two tools are complete, and 12 are incomplete (Tables 35 and 36). The mean length, width, thickness, and weight are very similar to the same attributes for distally-modified unifacial tools. A number of retouched flakes have been included in this category (Figure 81).

Both distally-modified and laterally-modified unifacial tools comprise a small proportion of the total assemblage. Similar unifacial tools are relatively scarce in other southwestern lithic assemblages. For example, all unifacial chipped stone implements represent 3.4 percent of the total lithic assemblage (1,597 tools) from 30 excavated sites on Northern Black Mesa (Cameron 1987).

PERFORATORS AND GRAVERS

Twenty-nine flaked stone tools were classified as perforators and gravers. Perforators include both bifacial specimens (Figure 82a-c) and unifacial specimens (Figures 82d, 83a-d) that exhibit elongated bits. These implements are tentatively assumed to represent tools used for drilling holes in durable raw materials like wood or bone. They may also have been used to make

perforations in animal hides. One specimen is made from a reworked Elko series projectile point (Figure 82a). A second perforator was apparently produced from a reworked longitudinally-split projectile point fragment (Figure 82c). A third specimen (Figure 82b) was manufactured from a wide expanding flake; the thin, well-formed perforator bit was produced by retouching one corner of the distal end of a biface thinning flake. Seven distal bit fragments and five medial bit segments were also recovered; descriptive statistics for maximum length, width, and thickness, and weight are provided in Tables 37-38, while Table 39 summarizes proximal fragments.

Gravers include a total of seven flakes or flake fragments that exhibit pronounced points, "beaks," or projections (Figures 82e,f,g; 83e-h; Table 40). These projections typically exhibit a plano-convex cross section and unifacial modification. These implements may have been utilized as lathe-like tools for cutting wood, antler, or bone.

CORES

Twenty-five cores and 24 core fragments are included in the total lithic assemblage. The cores were classified into three general categories: unifacial cores (N=10), exhausted cores (N=14), and block cores (N=1). Unifacial or unidirectional cores consist of relatively thick flakes or tabular pieces from which flakes have been removed from a common platform (Table 41; Figure 84). This form is roughly comparable to the conical or single platform core category defined by Cameron (1987:105). The unifacial cores exhibit relatively comparable mean maximum lengths (49.66 mm) and widths (47.50 mm). The mean weight for this core category equals 52.56 grams (Table 41).

Exhausted cores are relatively small pieces of siliceous raw material that exhibit numerous flake scars, roughly equivalent lengths and widths, and a mean weight less than 28 grams (Table 42). This form corresponds to the exhausted core category defined by Cameron (1987:105). These cores may be small, thick bifaces (Figure 85a,b), or they may exhibit multiple striking platforms (Figure 85c,d). It is assumed here that suitable flakes could no longer be removed via hard or soft hammer methods once core length, width, and thickness ratios approached 1.0.

In addition, the total lithic assemblage also contains 24 core fragments. These fragments include angular portions of debris exhibiting flake scars, as well as portions of single platform, multiplatform, bifacial, and block cores. Descriptive statistics for core fragment dimensions and weight are provided in Table 43.

Five "tested" cobbles of cryptocrystalline raw material that exhibit two or more flake scars may also have served as cores. They range in mean maximum length from 35.10 mm to 72.00 mm, and mean maximum width from 64.20 mm to 102.50 mm Their weights varied from 9140 grams to 40235 grams (see Table 44).

HAMMERSTONES

A total of fifteen hammerstones were collected during the course of surface survey and excavation. These hammerstones are ovoid or subspherical in shape and range in maximum length from 30.80 mm to 112.00 mm, in maximum width from 42.90 mm to 97.00 mm, and in maximum thickness from 20.60 mm to 64.60 mm (Table 45). The mean weight equals 233.96 grams; however, specimen weights range from a minimum of 60.70 grams to a maximum of 804.60 grams.

These hammerstones were produced from exhausted cores (Figure 86a), cobble fragments (Figure 86b,c,d), and modified cobbles (Figure 86e). Raw materials used included chalcedony, quartzite, or chert. They exhibit marked crushing and battering along prominent flake scar ridges and/or "distal"'and "proximal"ends. The hammerstones can be roughly separated into three general size classes—small, intermediate, and large.

DEBITAGE

Debitage resulting from core production, core reduction, tool manufacture, and tool maintenance equals 99 percent of the flaked stone assemblage. The excavated debitage that represents approximately 10 percent of the total debitage was analyzed. The excavated assemblage consists of 9,395 complete and incomplete flakes, as well as angular pieces or shatter.

Description and Analysis

Seven variables were recorded for each debitage specimen—debitage type, completeness, use wear, raw material, amount of cortex, size, and weight. Debitage types and their numbered computer codes are: (1) initial reduction flake, (2) thinning flake, (3) lipped thinning flake, (4) pressure flake, (5) shatter, or (6) unidentifiable piece. These debitage types are based on the classification used by Tipps (1984) for analysis of the lithic debris from Captain's Alcove in Glen Canyon National Recreation Area. Initial reduction flakes are usually angular and thick in cross section; they lack prepared striking platforms and may exhibit up to 100 percent cortical coverage. Thinning flakes exhibit high length-to-width ratios; thin, curved longitudinal cross sections; a prepared striking platform; dorsal flake scars; and relatively little cortex. Lipped thinning flakes generally possess a smoothed or ground striking platform that extends onto the ventral flake surface. Pressure flakes are usually smaller and thinner and have a small bulb of force with a prepared and, frequently, abraded platform. Shatter consists of angular pieces of raw material that lack flake characteristics such as striking platforms, bulbs of percussion, and flake terminations.

Debitage completeness includes two categories: 1 = complete and 2 = incomplete, in reference to flake types. Incomplete flakes lack a striking platform and bulb of force, a flake termination, or both. Use wear includes two categories: 1 = utilization and 2 = modification. Utilization includes minor, discontinuous edge modification of flake margins. This use-wear category is most apt to include edge damage attributable to natural formation processes, including trampling. Modification refers to edge alteration that includes a relatively continuous series of retouch flake scars along a portion of the flake margin. The raw material categories and their computer codes include: (1) chert, (2) chalcedony, (3) quartzite, (4) quartz, (5) obsidian, and (6) other/unidentifiable. Cortex includes cortical areas that are (1) less than 50 percent, (2) greater than 50 percent, (3) equal to zero percent, or (4) equal to 100 percent. Flake or debitage size is based on flake placement within a series of concentric circles with graduated diameters. Flake weight was measured to the nearest 0.01 gram using an Ohaus Autogram 2000 electronic scale.

The results of the descriptive statistical analysis of complete flakes, incomplete flakes, and shatter for six excavated sites are presented in Tables 46-48. Comparative data regarding mean flake size and weight for these six excavated sites is presented in Figures 87-89. The coefficients of variation for both mean flake size and weight are illustrated in Figures 90 and 91.

Interpretations

As noted, approximately 99 percent of the lithic assemblage is debitage. A great proportion of the analyzed subsurface debitage from sites 42GR2025, 42SA3278, 42SA8500, 42SA8512, and 42SA8503 consists of thinning and pressure flakes (Figure 92). Shatter, or angular debris that is characteristic of the early stages of raw material reduction, occurs in very low frequencies (Figure 92). Also, most of the subsurface debitage does not exhibit any cortex (Figure 93). Given these contrasts, one might suggest that lithic raw material was transported to this area in the form of prepared cores. This suggestion receives additional empirical support from the results of our investigations at the White Crack site (42SA17596), which is located on the White Rim several kilometers south of the project area (Osborn and Vetter 1989). The White Crack site (42SA17596) is a large lithic scatter that is associated with a large chert outcrop in the Cedar Mesa Sandstone. A cumulative percentage curve of flake size suggests that the primary activity at this location was biface manufacture (see Stahle and Dunn 1982). Chert bifaces or bifacial cores were apparently transported from the White Crack site (42SA17597) to other locations in the region, including the Island-in-the-Sky.

Core production and reduction strategies, then, can provide us with further insights into prehistoric means for lithic resource procurement and use. These insights are gained within the broader context of aboriginal patterns of land use. Foragers are expected to procure lithic raw materials for stone tool production in the context of residential group movement throughout their home ranges during the annual cycle. Given forager mobility constraints and low bulk processing responses, we would expect relatively low inputs of lithic debris into the archeological record at any one time. Absolute lithic assemblage size can be expected to vary as a function of the frequency of re-occupation or use of

a given location. Raw material sources, including surface and subsurface deposits, would be visited by residential groups. Lithic resources would be tested, procured, and modified in relatively limited quantities in the context of associated occupational activities, e.g., food, fuel, and water procurement; food processing and consumption; shelter construction; and tool maintenance.

On the other hand, collectors are expected to obtain lithic materials in the context of logistically organized activities. Binford (1979:270) states that for ".. systems organized logistically ... raw materials or tools are rarely obtained through direct procurement strategies...." Kelly (1983:298) states, "There is more to logistical mobility ... than the direct acquisition of resources.... Many stationary nonfood resources, such as material for stone tools, can be collected during successful or unsuccessful logistical forays." Lithic procurement for collectors is not expected, then, to occur in association with residential activities. Binford (1979) argues that lithic raw material procurement would most probably be embedded within multipurpose logistical trips.

Recently, Parry and Kelly (1987) have presented an explanatory model regarding marked shifts in prehistoric North American lithic technology. The archeological record for the Eastern Woodlands, the Great Plains, the Southwest, and Mesoamerica exhibits a marked shift from bifacial, formalized tools and standardized cores toward increased use of unretouched flake tools and expedient cores. These technological changes occurred between 1500-1000 B.C. in Mesoamerica and between A.D. 300-600 in temperate North America (Parry and Kelly 1987:295). Paleoindian and Archaic populations made greater use of formalized tools and a standardized core technology. This approach to lithic technology produces

> bifaces and other retouched formal tools [that] are multifunction and multiuse implements: multifunction, because their generalized forms can be easily altered to be suitable for a wide variety of tasks; multiuse, because the tool can be resharpened and reused repeatedly for the same task (Parry and Kelly 1987:298).

Parry and Kelly (1987:298) continue,

> Standardized core technology also allows production of more usable cutting edge per unit mass. Bifaces, for example, can be used as highly efficient cores for the production of flake tools, because each flake removed from a biface has a high edge-to-weight ratio .... In short, formalized technology is more portable because it permits a fixed set of tool needs to be filled with a smaller number of tools made from a smaller weight of raw material.

This shift in emphasis of lithic technology cannot be understood in terms of the depletion of raw materials; adoption of the bow and arrow, ceramics, or ground stone implements; or the shift toward horticulture. Increased dependence on expedient core technology and flake tools is best explained in relation to a significant reduction in residential mobility and the appearance of large, nucleated, permanent villages (Parry and Kelly 1987:297). A major reduction in residential mobility is frequently associated with collapsed home range size(s), regional population packing, and the emergence of territoriality (Binford 1982, 1983). Reduced home range size and residential mobility may restrict access to high-quality raw materials for lithic tool production. If access were restricted, one might expect to observe increased use of expedient core technology and flake tools associated with sedentary groups. Parry and Kelly (1987:300-301) point out that expedient core technology may also be utilized by highly mobile hunter-gatherers, if suitable lithic raw materials can be readily acquired when and where they are needed.

Kelly offers a number of provocative ideas regarding the potential roles of bifaces in aboriginal technological systems. He (1988:718) emphasizes that bifaces reflect a "relatively high-energy investment ... not to be discarded quickly ...." He (1988:718) points out that bifaces may " ... play one or more of three different organizational roles in a technology."Large bifaces may serve as cores or sources for a number of thin, sharp flake tools; large bifaces exhibit a very high "edge-to-weight ratio"(Kelly 1988:718). Bifaces may exhibit long use lives, given their durability and resharpening potential. They may also be transformed into a number of different tool types. And, finally,

bifaces may exhibit "stylistic" formal characteristics that appear as a result of hafting considerations or primary tool function (Kelly 1988:718).

In addition to these observations regarding core production and reduction and aboriginal mobility strategies, we should emphasize the paucity of flaked stone implements in the total lithic assemblage. More than 99 percent of the total lithic assemblage consists of complete and incomplete flakes. We can assume that a number of flaked stone tools have been collected from artifact scatters in the area. In general, however, we suggest that much of the debitage was actually produced and/or used in the context of manufacturing wooden implements, e.g., digging sticks, throwing sticks, bows, arrow and dart shafts, and fire drills, and wooden or vegetal fiber facilities, e.g., winnowing dishes, baskets, and cradle boards. Flaked stone implements were probably also used to manufacture hide bags, bow quivers, mocassins, fiber sandals, articles of clothing, and tumplines.

In this regard, Hayden (1978) argues that flaked stone tools are characteristically associated with procurement and processing of animal food resources and by-products, including hides for clothing and shelter and bone or ivory or antler for implements and tool components. He (1978:184) states that, "Contrary to this common assumption [that chipped stone tools were used primarily for plant procurement and processing], there is very little in the ethnographic literature anywhere in the world to provide support for the notion."

Hayden (1978:188-191) emphasizes that aboriginal peoples in Western Australia use large quantities of lithic materials for the procurement of suitable raw materials and the subsequent manufacture of wooden implements, i.e., spears, spear throwers, winnowing bowls, digging sticks, throwing sticks, adze hafts, shields, and ritual items like bullroars and chiringas.

Given this argument, we propose that a significant proportion of the tool assemblage made and used by the prehistoric inhabitants of this region consisted of perishable material. The lithic assemblage from the Island-in-the-Sky District suggests that mobile hunter-gatherers fashioned high quality lithic raw material into bifacial cores. These cores were, in turn, transported throughout a portion of the annual range and flakes were produced when needed. These flake tools were then used to make implements and facilities from wood, vegetal fiber or plaiting, and/or animals skins and hides.

Table 29. Attributes for large thin bifaces.

Specimen number	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)	Raw material
T116-63W	155.00	68.40	13.30	145.50	Chalcedony
T116-64W	163.00	66.90	19.70	214.70	Chalcedony
T106-9W	85.40*	56.70	7.20	26.55	Chert

* Incomplete implement.

Table 30. Attributes for Intermediate size, thin bifaces.

Specimen number	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)	Raw material
T108-88E	72.20	34.90	7.75	23.10	Chert
FS56-1W	44.10	24.65	7.60	8.50	Chalcedony
T145-9E	67.00	32.00	5.90	12.70	Chert
FS91-148W*	98.50	32.60	7.45	15.90	Chert

* Alternately bevelled bifacial implement.

Table 31. Attributes for miscellaneous incomplete bifaces.

Attribute	Mean	Min.	Max.	Range	s.d.'	C.V.
Maximum length (mm)	26.41	4.5	98.7	94.20	15.03	0.57
Maximum width (mm)	21.07	4.5	74.8	70.35	11.76	0.56
Maximum thickness (mm)	6.70	0.2	28.4	28.20	4.41	0.66
Max. L/ Max. T.	3.54	1.1	8.3	7.21	1.32	0.37
Weight (g)	6.73	0.1	130.2	130.15	12.00	1.78

(N = 406)

Table 32. Results of correlational analyses of attributes for miscellaneous incomplete bifaces.

Attributes	r	R	R*	df	p
Weight and Thickness**	0.7436	0.5540	0.5529	403	0.000
Width, Thickness, and Weight	0.8018	0.6429	0.6411	403	0.000
Max. length, width, and thickness	0.8123	0.6625	0.6599	403	0.000

* R (coefficient of determination) is adjusted in order to remove the effect of sample.
** Regression analysis is weighted with respect to maximum length variable.

Table 33. Descriptive statistics for incomplete distally modified tools.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	33.98	32.22	9.25	11.84
Minimum	9.60	12.60	1.65	0.20
Maximum	59.10	45.40	18.25	39.40
Range	49.50	32.80	16.60	39.20
s.d.'	13.24	9.20	4.26	10.88
C.V.	0.39	0.28	0.46	0.92

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 9)

Table 34. Descriptive statistics for complete, distally modified tools.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	51.34	34.33	12.04	23.37
Minimum	27.80	27.60	6.00	4.00
Maximum	74.10	51.90	17.60	61.95
Range	46.30	24.30	11.60	57.95
s.d.'	17.41	8.41	3.21	17.82
C.V.	0.34	0.24	0.27	0.76

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 14)

Table 35. Descriptive statistics for incomplete, laterally modified tools.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	34.46	26.27	8.04	9.57
Minimum	10.50	12.00	2.10	0.40
Maximum	65.10	45.90	21.70	50.70
Range	54.60	33.90	19.60	50.30
s.d.'	15.35	9.72	4.78	12.22
C.V.	0.45	0.37	0.59	1.28

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 12)

Table 36. Descriptive statistics for complete, laterally modified tools.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	54.05	35.72	9.92	22.78
Minimum	24.65	22.40	3.80	2.70
Maximum	82.40	58.60	20.30	98.00
Range	57.75	36.20	16.50	95.30
s.d.'	18.46	10.27	4.90	26.77
C.V.	0.34	0.29	0.49	1.17

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 32)

Table 37. Descriptive statistics for distal fragments of perforators.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	15.23	8.53	3.52	0.71
Maximum	35.00	16.35	6.55	3.30
Minimum	7.30	6.00	1.90	0.10
Range	7.30	10.35	4.65	3.20
s.d.'	10.00	3.68	1.59	1.16
C.V.	0.66	0.43	0.45	1.63

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 7)

Table 38. Descriptive statistics for medial sections of perforator shafts.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	21.39	9.53	4.83	1.28
Maximum	25.85	14.70	7.55	2.70
Minimum	11.50	5.30	2.60	0.20
Range	14.35	9.45	4.95	2.50
s.d.'	5.74	3.36	2.04	0.93
C.V.	0.27	0.35	0.42	0.72

s.d.' - sample standard deviation; C.V. - coefficient of variation.
(N = 5)

Table 39. Descriptive statistics for proximal fragments of perforators.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	24.95	18.27	4.76	2.72
Maximum	43.80	31.10	11.35	8.80
Minimum	8.00	6.30	1.70	0.30
Range	35.80	24.80	9.65	8.50
s.d.'	13.38	7.91	2.72	3.02
C.V.	0.54	0.43	0.57	0.57

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 10)

Table 40. Descriptive statistics for gravers.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	36.47	25.62	7.20	9.23
Maximum	53.40	47.10	16.00	34.80
Minimum	19.20	14.10	3.40	1.00
Range	34.20	33.00	12.60	33.80
s.d.'	12.22	11.34	4.47	12.06
C.V.	0.33	0.44	0.62	1.31

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 7)

Table 41. Descriptive statistics for unifacial cores.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	49.66	47.50	18.76	52.56
Minimum	26.50	39.20	13.00	17.80
Maximum	61.90	66.10	25.00	119.30
Range	35.40	26.90	12.00	101.50
s.d.'	11.53	8.16	5.18	30.50
C.V.	0.23	0.17	0.28	0.58

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 10)

Table 42. Descriptive statistics for exhausted cores.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	38.43	35.32	15.70	23.94
Minimum	16.00	27.80	8.90	1.60
Maximum	64.60	47.75	28.80	38.80
Range	48.60	19.95	19.90	37.20
s.d.'	13.64	5.80	6.37	10.74
C.V.	0.35	0.16	0.41	0.45

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 12)

Table 43. Descriptive statistics for core fragments.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	47.12	42.93	16.17	39.44
Minimum	22.00	27.60	10.00	11.40
Maximum	98.70	74.85	32.80	130.20
Range	76.70	47.25	22.80	118.80
s.d.'	18.51	12.74	5.42	33.25
C.V.	0.39	0.30	0.33	0.84

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 24)

Table 44. Descriptive statistics for tested cobbles.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)
Mean	45.63	83.21	—	251.01
Minimum	35.10	64.20	—	91.40
Maximum	72.00	102.50	—	402.35
Range	36.90	38.30	—	310.95
s.d.'	15.35	15.60	—	129.50
C.V.	0.34	0.19	—	0.92

s.d.' – sample standard deviation; C.V. – coefficient of variation.
(N = 5)

Table 45. Attributes for specific hammerstone specimens.

	Maximum length (mm)	Maximum width (mm)	Maximum thickness (mm)	Weight (g)	Raw Material
Small:					
FS120-4E	61.60	60.20	37.20	152	Chalcedony
T168-26E	56.40	52.40	27.90	94	Chert
FS107-15W	60.50	52.40	20.60	61	Chalcedony
FS111-664E	67.10	63.60	47.80	157	Chalcedony
FS137-2E	53.70	42.90	24.40	70	Chalcedony
Intermediate:					
FS150-365W	72.20	54.10	46.00	242	Chert
T160-3E	78.35	58.50	47.20	283	Chalcedony
Large:					
FS129-161E	78.50	61.00	43.30	471	Chalcedony

Table 46. Descriptive statistics for complete flakes.

Site Number		Size (mm)	Weight (g)
42GR913 (N=215)	Mean	20.93	1.28
	s.d.'	10.78	4.20
	C.V.	0.52	3.29
	Min.	5.00	0.05
	Max.	80.00	50.70
	Range	75.00	50.65
42SA8502e (N=70)	Mean	22.71	0.93
	s.d.'	7.41	1.87
	C.V.	0.33	2.01
	Min.	10.00	0.05
	Max.	50.00	11.90
	Range	40.00	11.85
42SA8502w (N=483)	Mean	15.77	0.70
	s.d.'	17.72	2.53
	C.V.	1.12	3.62
	Min.	5.00	0.05
	Max.	30.00	29.70
	Range	29.50	29.65
42SA8506 (N=65)	Mean	33.85	6.03
	s.d.'	16.46	11.65
	C.V.	0.49	1.93
	Min.	10.00	0.10
	Max.	90.00	71.20
	Range	80.00	71.10
42SA8512 (N=42)	Mean	15.59	0.68
	s.d.'	11.87	2.09
	C.V.	0.74	3.07
	Min.	5.00	0.05
	Max.	60.00	13.20
	Range	80.00	71.10
42SA16858 (N=66)	Mean	30.60	3.54
	s.d.'	12.26	5.91
	C.V.	0.40	1.67
	Min.	10.00	0.05
	Max.	80.00	41.35
	Range	70.00	41.30
Total Assemblage (N=4343)	Mean	20.79	0.98
	s.d.'	12.06	2.86
	C.V.	0.58	2.91
	Min.	<1.00	0.01
	Max.	10.00	71.20
	Range	10.00	71.19

Table 47. Descriptive statistics for incomplete flakes.

Site Number		Size (mm)	Weight (g)
42GR913 (N=1286)	Mean	18.92	0.51
	s.d.'	8.52	1.21
	C.V.	0.45	2.38
	Min.	5.00	0.05
	Max.	200.00	23.60
	Range	195.00	23.55
42SA8502e (N=150)	Mean	22.87	1.17
	s.d.'	10.32	2.24
	C.V.	0.45	1.92
	Min.	10.00	0.05
	Max.	70.00	13.40
	Range	60.00	13.35
42SA8502w (N=1458)	Mean	17.89	0.64
	s.d.'	11.22	1.73
	C.V.	0.63	2.72
	Min.	5.00	0.05
	Max.	100.00	20.60
	Range	95.00	20.55
42SA8512 (N=92)	Mean	26.70	2.65
	s.d.'	12.26	5.75
	C.V.	0.46	2.17
	Min.	10.00	0.05
	Max.	70.00	35.20
	Range	60.00	35.15
42SA8512 (N=92)	Mean	17.72	0.48
	s.d.'	10.12	0.89
	C.V.	0.57	1.84
	Min.	5.00	0.05
	Max.	50.00	6.90
	Range	45.00	6.85
42SA16858 (N=66)	Mean	28.64	2.34
	s.d.'	11.75	3.92
	C.V.	0.41	1.67
	Min.	10.00	0.05
	Max.	70.00	19.50
	Range	60.00	19.45
Total assemblage (N=4589)	Mean	19.91	0.93
	s.d.'	10.83	27.87
	C.V.	0.54	2.30
	Min.	<1.00	0.05
	Max.	10.00	71.20
	Range	10.00	71.15

Table 48. Descriptive statistics for shatter.

Site Number		Size (mm)	Weight (g)
42GR913 (N=91)	Mean	18.79	0.93
	s.d.'	7.12	1.42
	C.V.	0.38	1.53
	Min.	10.00	0.10
	Max.	50.00	8.60
	Range	40.00	8.50
42SA8502e (N=13)	Mean	16.92	0.42
	s.d.'	6.30	0.62
	C.V.	0.37	1.49
	Min.	10.00	0.05
	Max.	30.00	2.40
	Range	20.00	2.35
42SA8502w (N = 86)	Mean	19.46	1.08
	s.d.'	8.71	1.79
	C.V.	0.45	1.66
	Min.	5.00	0.05
	Max	40.00	9.40
	Range	35.00	9.35
42SA8506 (N=53)	Mean	22.08	1.04
	s.d.'	7.69	1.66
	C.V.	0.35	1.60
	Min.	10.00	0.05
	Max.	40.00	10.20
	Range	30.00	10.15
42SA8512 (N=2)	Mean	20.00	0.25
	s.d.'	0.00	0.07
	C.V.	0.00	0.28
	Min.	20.00	0.20
	Max.	20.00	0.30
	Range	0.00	0.10
42SA16858 (N=28)	Mean	22.14	1.70
	s.d.'	10.67	3.55
	C.V.	0.48	2.09
	Min.	10.00	0.10
	Max.	60.00	14.10
	Range	50.00	14.00
Total assemblage (N=273)	Mean	19.96	1.05
	s.d.'	8.20	1.99
	C.V.	0.41	1.88
	Min.	<1.00	0.05
	Max.	60.00	14.10
	Range	59.00	14.05

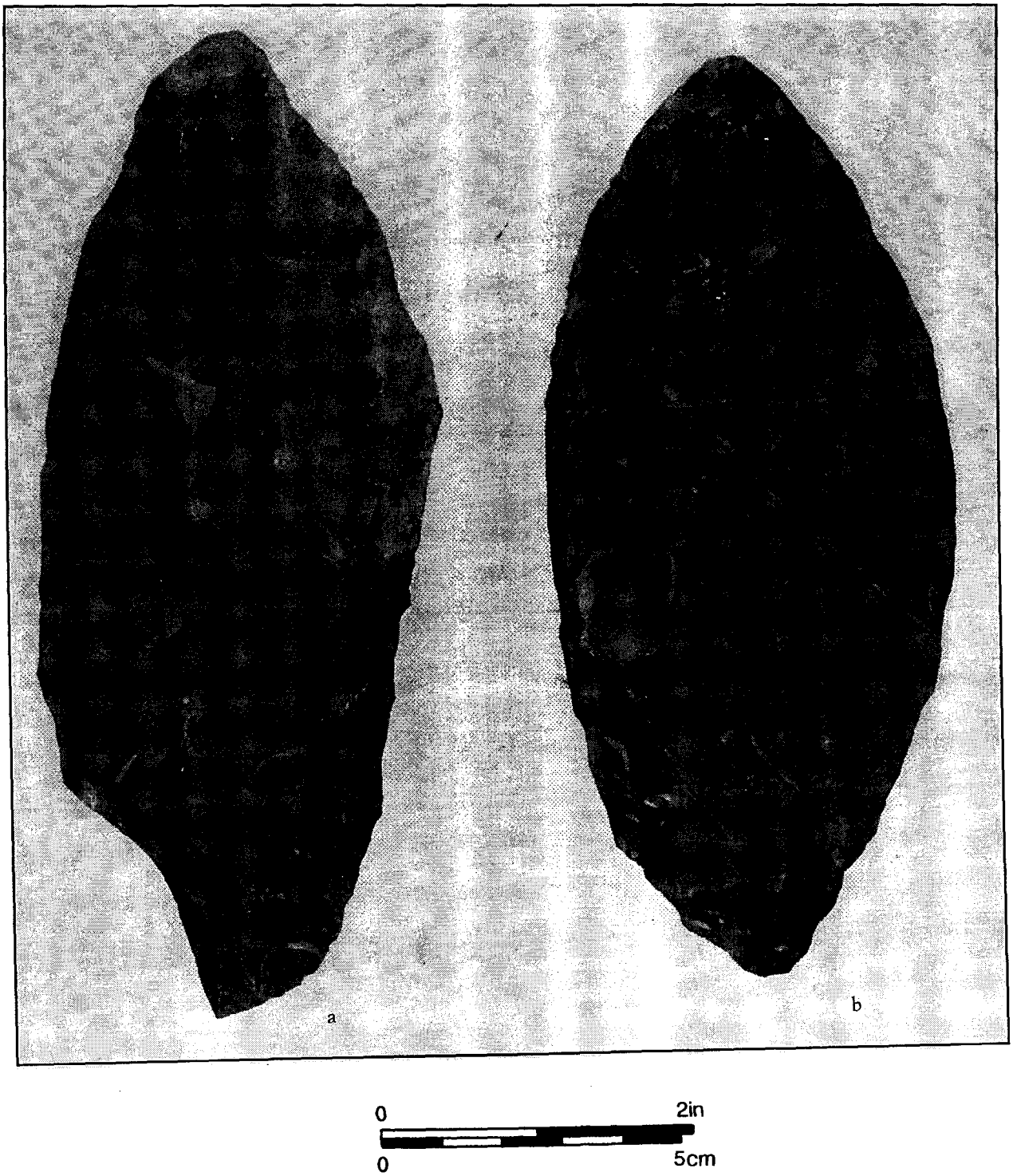


Figure 76. Large bifacial cores cached at the Neck site (42SA8502).

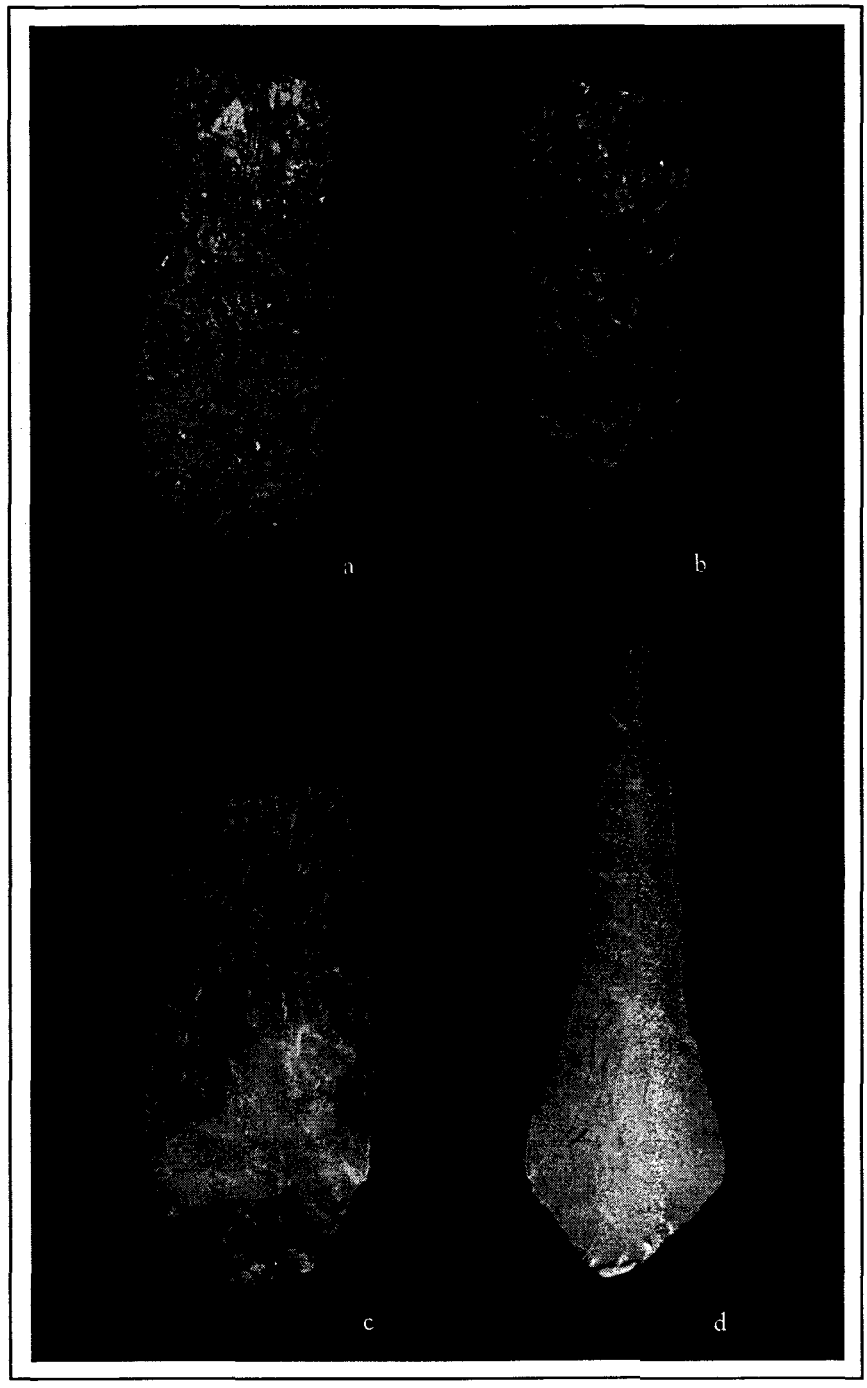


Figure 77. Intermediate size, thin bifaces.

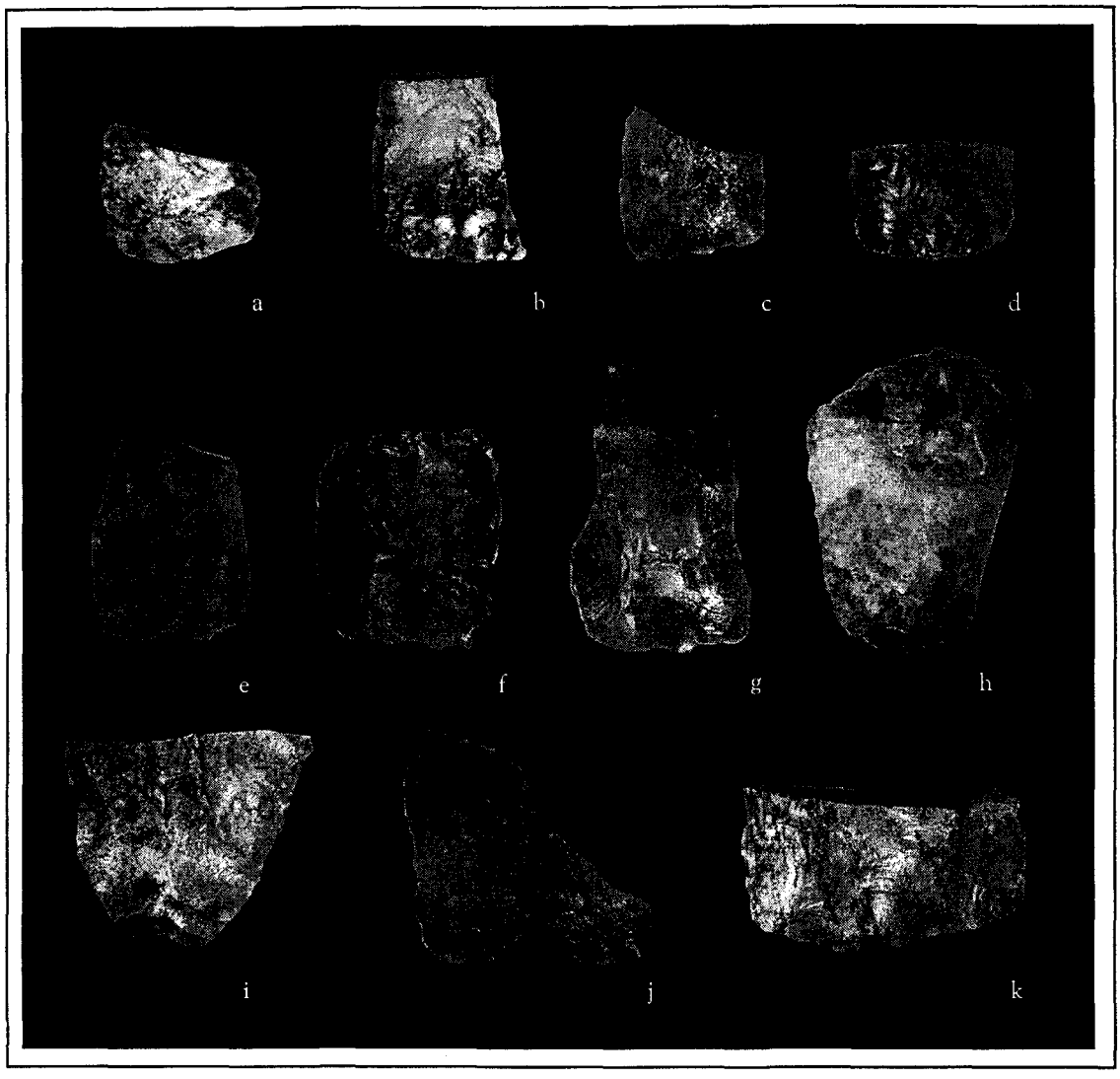


Figure 78. Incomplete, intermediate size, thin bifaces.

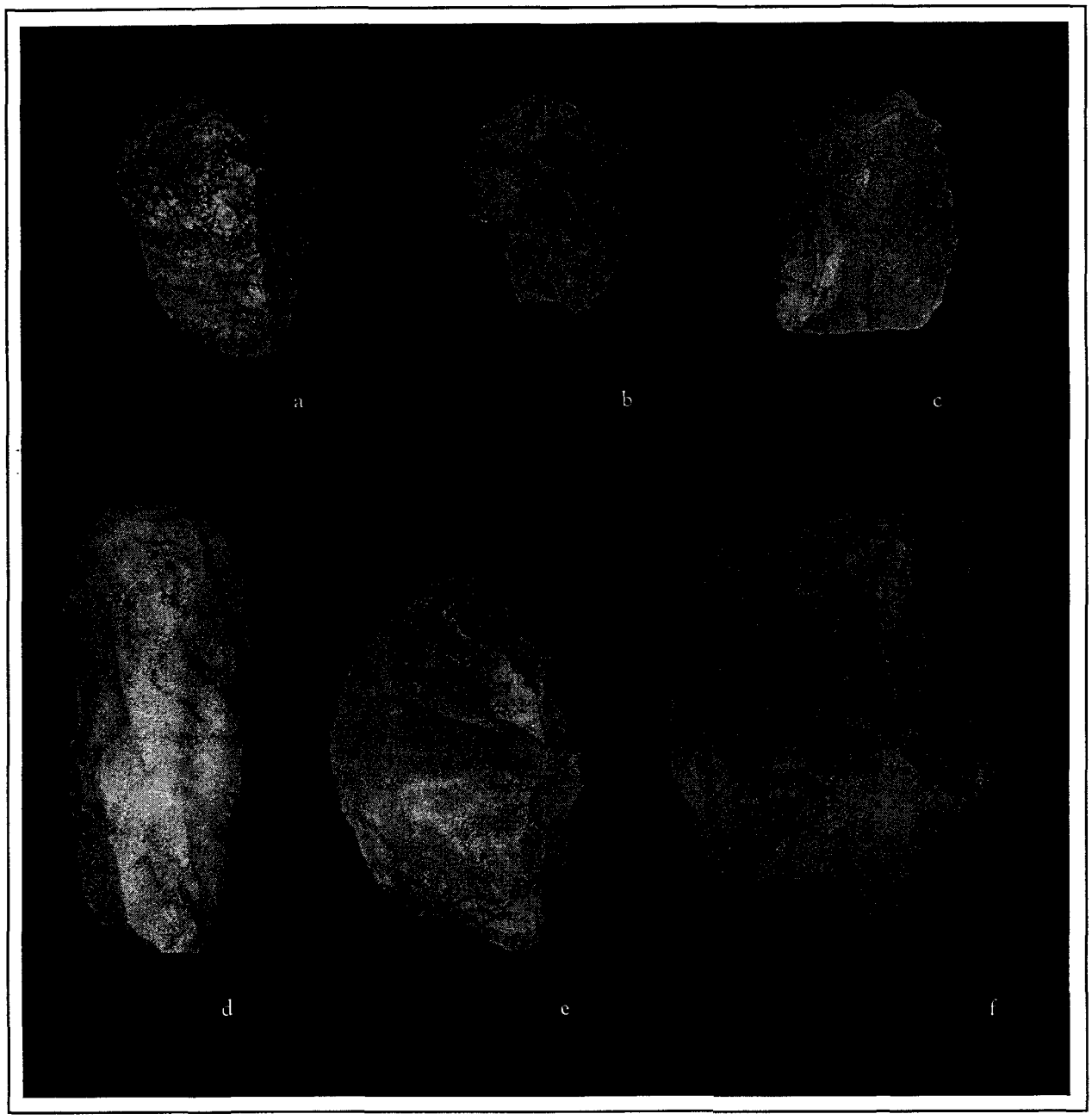


Figure 79. Distally-modified unifaces or endscrapers.

Figure 80. Distally-modified unifaces or endscrapers.

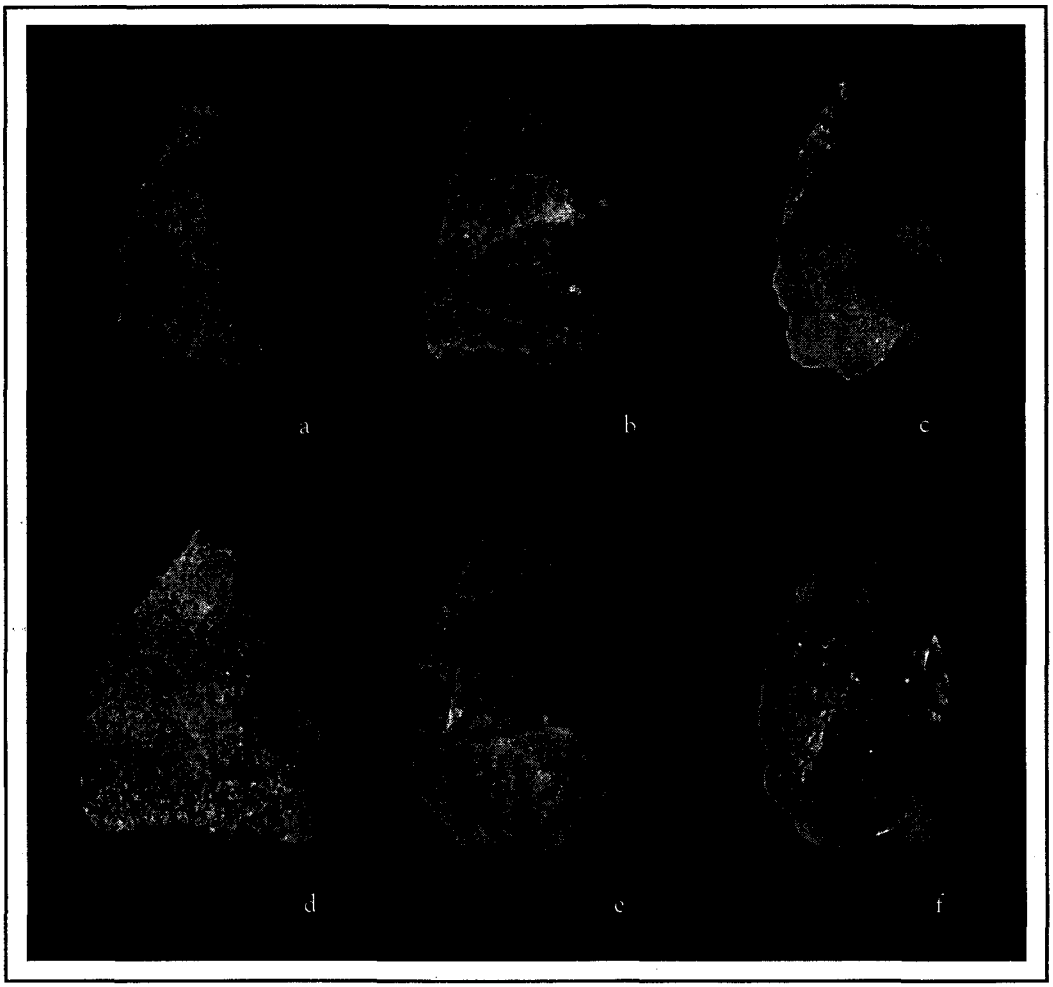


Figure 81. Laterally-modified unifaces produced from flakes.

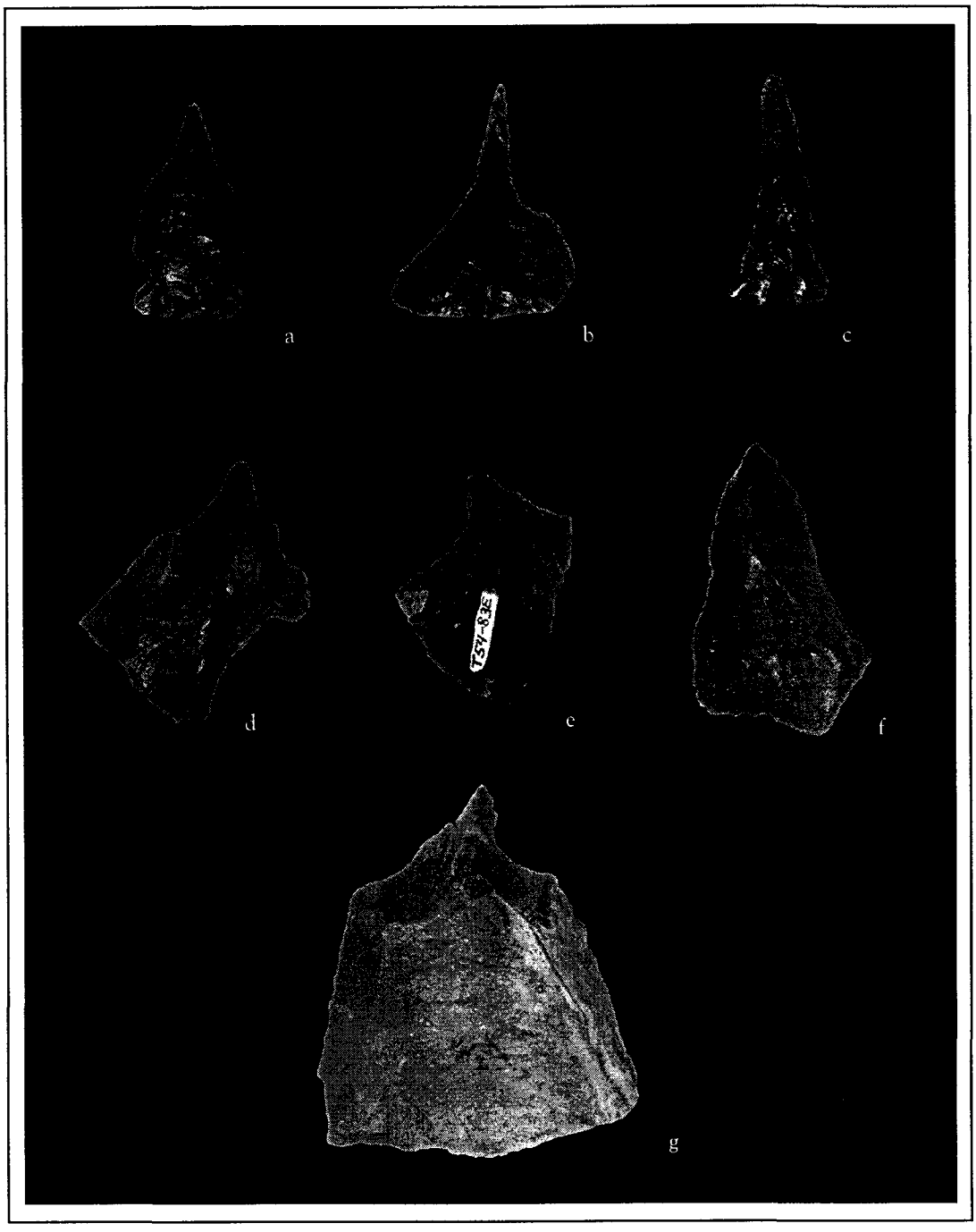


Figure 82. Flaked stone perforators and gravers.

Figure 83. Flaked stone perforators and gravers.

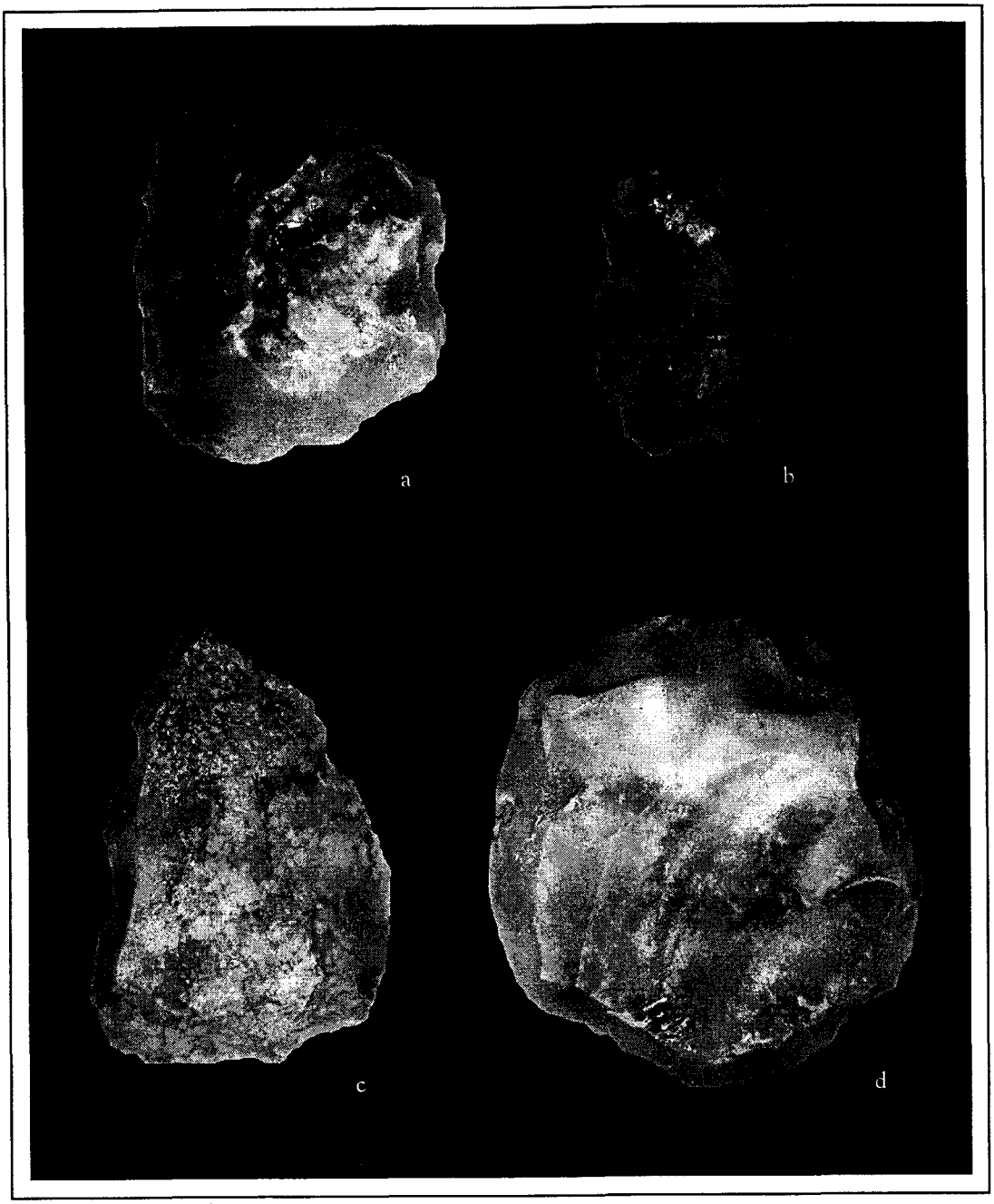
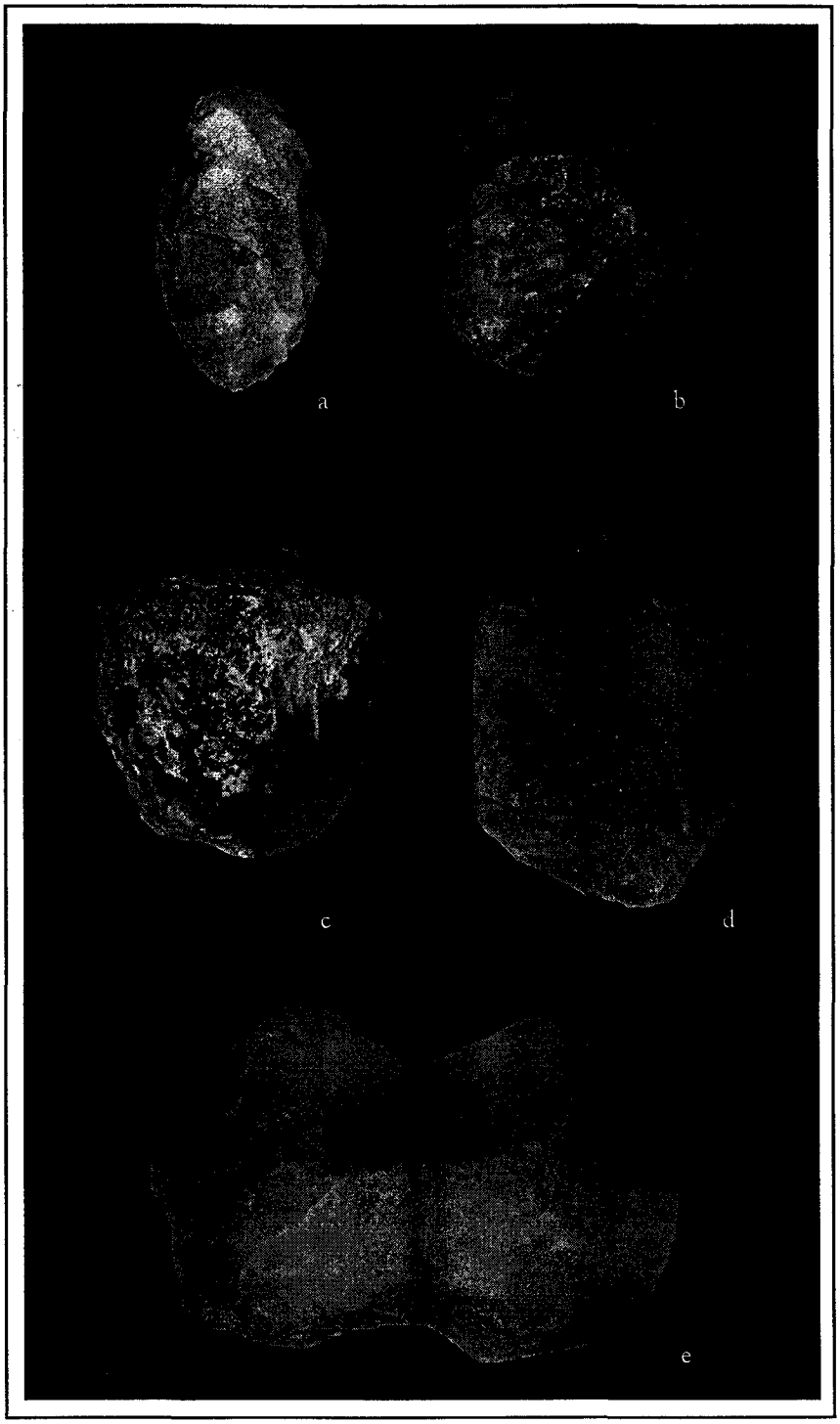


Figure 84. Unifacial or unidirectional cores.

Figure 85. Exhausted cores and core fragments.



0 2in
0 5cm

Figure 86. Hammerstones produced from exhausted cores, cobble fragments, and modified cobbles.

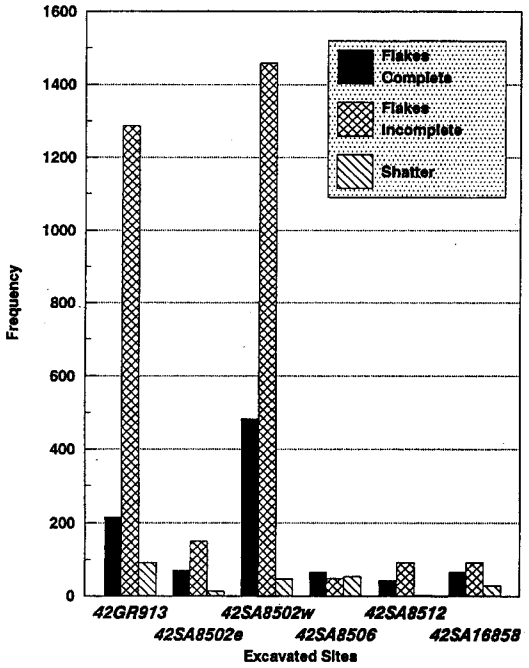


Figure 87. Subsurface lithic debitage frequencies.

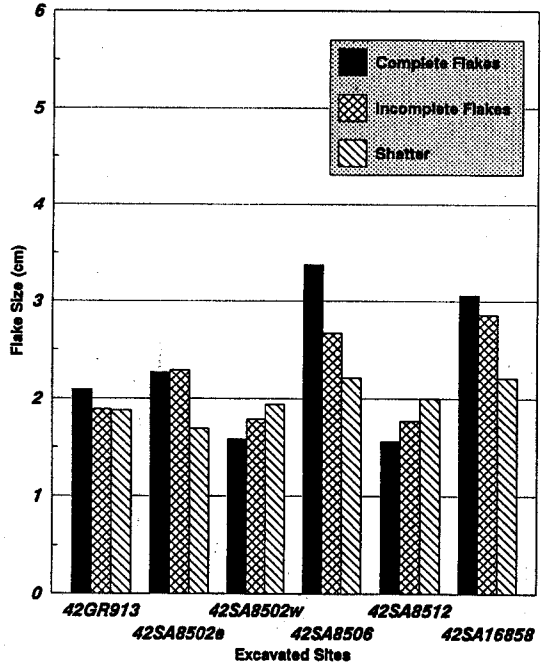


Figure 88. Subsurface lithic debitage size.

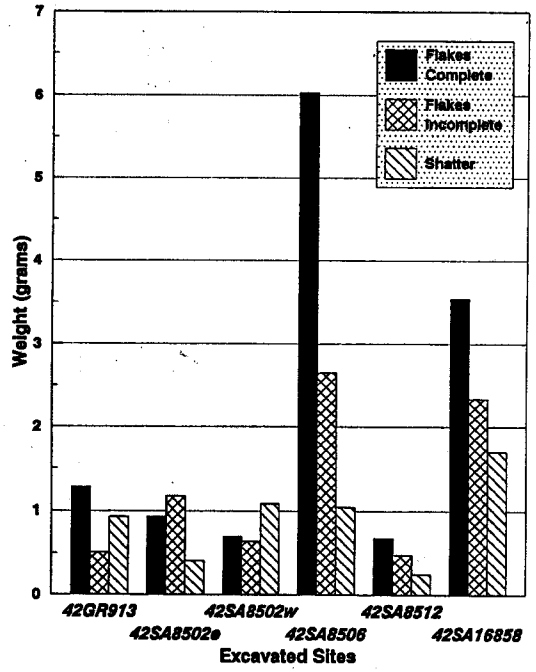


Figure 89. Subsurface lithic debitage weight.

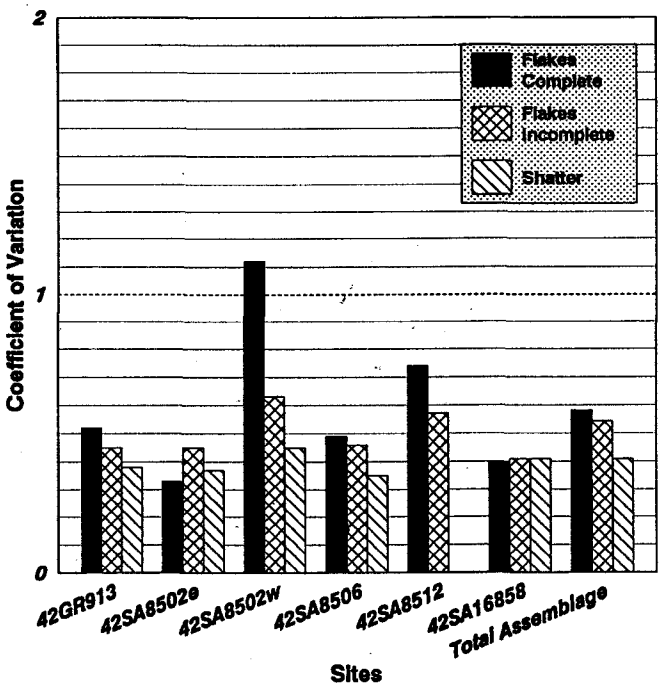


Figure 90. Coefficient of variation for subsurface lithic debitage size.

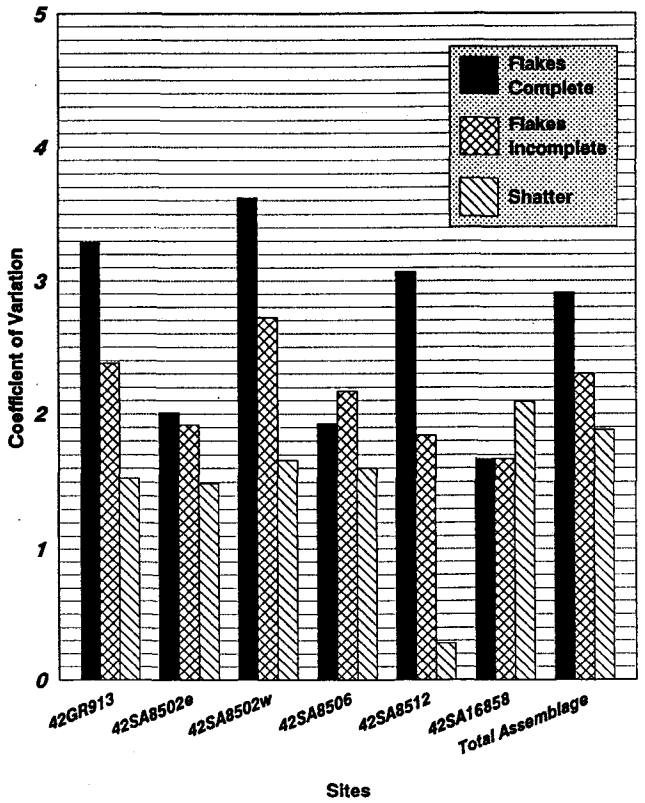


Figure 91. Coefficient of variation for subsurface lithic debitage weight.

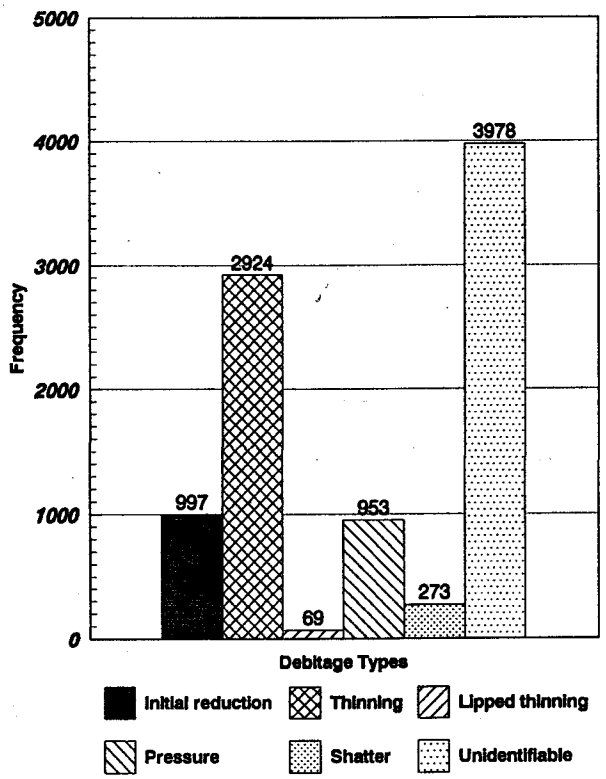


Figure 92. Subsurface debitage types.

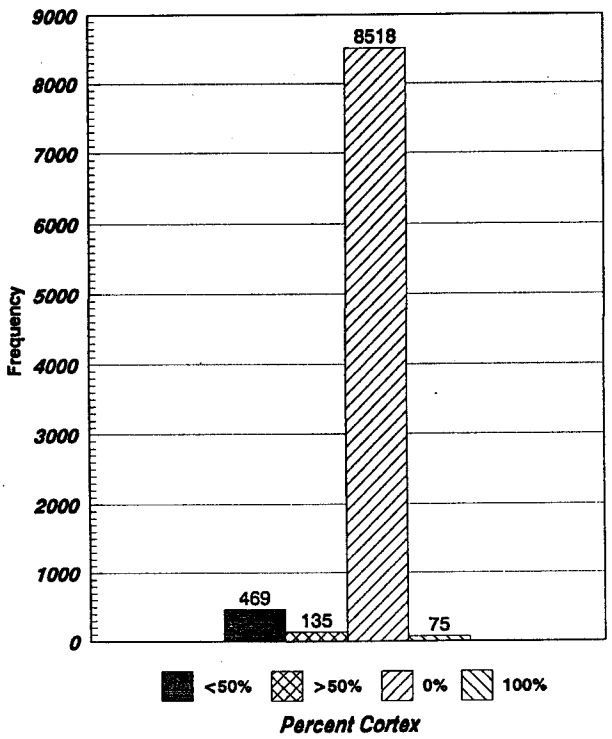


Figure 93. Percent cortex for subsurface debitage.

GROUND STONE ASSEMBLAGE

INTRODUCTION

Archeologists working in the American Southwest have been slow to realize the functional implications and the adaptive significance of ground stone tools – manos and metates. Recently, investigators have begun to provide us with greater insights into the variable relationships between ground stone implements and facilities and past human diet, food preparation techniques, and technological organization (e.g., Allen 1974; Christenson 1987; Kirk 1981; Lancaster 1986; Phagan 1988; Russell 1989; Tindale 1974, 1977). We will briefly review several of these studies of grinding tools, food processing methods, and technological organization in the American Southwest, prior to discussing specific ground stone tools recovered from the Island-in-the-Sky District of Canyonlands National Park.

One of the earliest detailed discussions of ground stone implements used for food processing in the American Southwest was presented by Barlett (1933). Barlett (1933:3) emphasized that manos and metates were essential for food processing, yet illustrations, detailed descriptions, and measurements of these tools were rarely included in the archeological literature for this region. Barlett (1933) proposed a developmental sequence for metates based on archeological and ethnographic specimens. This chronological sequence included early grinding slabs, later free-standing trough metates, and finally finished slab metates in milling bins. Mano shape and size were also discussed in relation to this developmental sequence that included single-hand manos, two hand rectangular manos, grooved manos, and two hand wedge-shaped manos.

This developmental sequence was based on the assumption that "... each new step made the task easier or quicker or more sociable for the women who were condemned to spend most of their life grinding corn" (Barlett 1933:29). Furthermore, Barlett (1933:29) argues that "Each step in the development was also dependent upon the practical question of how much room there was in the house."

Martin and Plog (1973:217) argued that grinding efficiency could be increased by increasing the pressure placed on the grinding stone. Lancaster (1983:188) takes issue with this proposal and states, "Efficiency of grinding is not obtained by increasing the grinding pressure on the grinding platform ...; rather, grinding efficiency is augmented by increasing the size of the grinding surface." Lancaster (1986:186) presents a table that illustrates that both trough and through-trough metates (758.8 and 1123.0 cm^2, respectively) exhibit significantly greater grinding areas than basin and slab metates (494.5 and 403.3 cm^2, respectively).

This chronological trend in mano types is succinctly described by Phagan (1988:181-183), who states,

> In general, small, round 1-hand manos and their associated basin metates tend to occur earliest in Southwestern archaeological contexts, and are the exclusive forms found in the late Archaic and early Basketmaker contexts.... One-hand manos and basin metates continue through most of the succeeding archaeological record, and this probably indicates continuing need for such generalized grinding implements.
>
> Larger, flat, subrectangular 2-hand manos and their associated trough metates begin to occur in late Basketmaker contexts, and they dominate grinding tool assemblages until about the middle of the Pueblo sequence.... Two-hand manos and trough metates are frequently characterized as specialized corn grinding implements with considerably improved efficiency resulting primarily from the capability to apply larger amounts of force during grinding.

Phagan (1988:182) continues this discussion of the developmental sequence for grinding implements that includes the later Pueblo II elongated two-hand mano, slab metate, and milling bin. This specialized food processing system was used through much of the historic period. Phagan (1988:182) challenges the assumption that such developmental changes can best be interpreted as efficiency responses. He (1988:182) argues that both forms exhibit relatively equivalent grinding surfaces and the later slab metate and milling bin requires greater shaping and construction costs. Phagan does not provide a quantitative assessment of variable grinding efficiencies or manufacturing costs of these implements, it is beyond the scope of this study to do so here. Such trends in increased use of facilities, increased tool specialization, and increased technological diversity are expected outcomes of decreased mobility, increased duration of site use or occupation, decreased diet breadth, bulk food processing and storage, more structured use of life space, and so forth (see Binford 1983; Hitchcock 1987; Torrence 1983).

METHODOLOGY

The observations recorded for ground stone implements include seven metrical and nine morphological attributes. The metrical attributes are: (1) maximum length (longitudinal axis); (2) maximum width (perpendicular to longitudinal axis); (3) maximum thickness (perpendicular to length and width plane); (4) weight; (5) ground surface length (longitudinal axis); (6) ground surface width (perpendicular to longitudinal axis); and, (7) ground surface area (product of ground surface length and width). All metrical dimensions were measured with a sliding vernier caliper or steel tape to the nearest 1.0 millimeter. Mano weights were obtained by using a Dial-O-Gram laboratory balance. Metate weights were measured using a metric tube scale and plastic bucket.

Nine morphological attributes are: (1) general tool type (mano, metate, or indeterminate); (2) raw material (sandstone, quartzite, and igneous rock); (3) completeness (complete or incomplete); (4) exterior modification (pecking, grinding, flaking, battering, or finger grooves); (5) number of prepared surfaces; (6) nature of prepared surface (ground, pecked, or grooved); (7) outline or shape (rectangular/square, ovoid/circular, oblong, or irregular); (8) mano cross section (tabular or biplano, biconvex, plano-convex, wedge, or indeterminate); metate form (basin, slab, trough, through-trough, or indeterminate).

In addition, palynological analyses were conducted in order to assess the nature of food resources that were processed on metates. Six pollen washes were completed using six metates that were recovered from a block excavation at the Gray's Pasture site (42SA16858). These analyses provide information that can be used to make firm inferences about the activities performed at this location in the Island-in-the-Sky District of Canyonlands. Specific data regarding the results of these pollen washes are presented later in this section.

DESCRIPTION AND ANALYSIS

Twenty complete and 34 incomplete manos were recovered during the course of the Island-in-the-Sky road project. Nineteen complete and 33 incomplete manos were recovered during survey and excavation. Complete manos range in size from 7.50 cm to 19.00 cm in length (mean, 13.13 cm), 6.90 cm to 10.90 cm in width (mean, 9.03 cm), and 1.50 cm to 6.60 cm in maximum thickness (mean, 4.03 cm) (Table 49). Weights vary from 115.40 grams to 1453.40 grams; mean weight equals 716.24 grams. Major grinding surface areas (GSA1) range from 36.00 cm^2 to 205.20 cm^2; mean surface area (GSA1) equals 103.98 cm^2. Secondary grinding surface areas (GSA2) exhibit a minimum of 27.95 cm^2, a maximum of 169.29 cm^2, and a mean of 87.48 cm^2. Measurements for the incomplete manos are provided in Table 50. Summary information for mano outline and cross section is provided in Tables 51 through 54.

Archeologists have traditionally subdivided manos into one-hand and two-hand categories (e.g., Barlett 1933; Eddy 1964; Russell 1989; Woodbury 1954). Maximum length distributions are generally used to distinguish between groups of one- versus two-hand manos (see Christenson 1987; Lancaster 1982; Russell 1989). The discontinuity in maximum lengths occurs between 14.0 cm and 17.0 cm (Christenson 1987:47; Lancaster 1986:18-20; Russell 1989:655).

Table 51 illustrates that the mean maximum length for ovoid manos equals 11.25 cm; this mano category, then, fits well within the single-hand mano

category discussed by other investigators in the American Southwest. Oblong manos, on the other hand, exhibit a mean maximum length equal to 15.19 cm; this category falls within the observed discontinuity for maximum length of one- versus two-hand manos described above (Table 52).

One-hand manos can be classified into two general categories, including relatively expedient "cobble manos" of quartzite or igneous material (Figure 94a, b) and shaped manos of fine- to medium-grain sandstone (Figure 95a, b). These shaped manos tend to exhibit two grinding faces, tabular or plano-convex cross sections, and smoothed and ground lateral edges.

The two-hand manos can be subdivided into three general categories including large, thick, rectangular manos; large, flat, rectangular manos with rounded edges; and large, thin, wedge-shaped manos. The large, flat, rectangular manos with rounded edges and corners and a convex working surface were used with trough metates (see Figure 96a, b).

Summary information for metates is presented in Tables 55 and 56. Four different metate forms are represented in the collection. The complete metates are illustrated in Figures 97-100. Eight metates were processed in order to recover plant pollen from their grinding surfaces. Detailed discussion of these palynological analyses are provided in the ecofactual assemblage section of this report. Table 57 contains summary information regarding the results of these pollen washes. Four metates recovered during excavations at the Gray's Pasture site (42SA16858) produced *Zea mays* pollen. Botanical analysis revealed that maize pollen collected from soil associated with corrugated ceramic vessels recovered at the Dunes site (42SA8506) and at the Gray's Pasture site (42SA16858) was torn and fragmented. This indicates that ground corn had been cooked and/or stored in these vessels. Similar torn grains of maize pollen were recovered from a mano and a widemouth ceramic vessel at Antelope House in Canyon de Chelly National Monument in northeastern Arizona (Morris 1986:491, Figure 277). Modern maize seed and pollen samples were experimentally ground with a prehistoric mano and metate. Torn maize pollen grains compared very closely with the prehistoric corn pollen recovered at this site.

Perhaps it is more interesting that the ground stone pollen washes suggest that aboriginal peoples processed a variety of wild plant resources. These plant food resources included goosefoot (*Chenopodium*), pigweed (*Amaranthus*), saltbush (*Atriplex*), beeweed (*Cleome*), Mormon tea (*Ephedra*), prickly pear cactus (*Opuntia*), plantain or Indian wheat (*Plantago*), buffaloberry (*Shepherdia*), and cattail (*Typha*). Aboriginal use of ground stone implements for processing wild plants will be discussed in more detail in the following section.

INTERPRETATION

Driver and Masey (1957) have pointed out that the geographical distribution of grinding stones (manos and metates) is restricted to the western halves of North and South America. This pattern coincides with the distribution of arid regions and their associated drought-resistant plant communities. In turn, "Seeds from such plants tend to be hard and dry and require the thorough grinding which is possible with stone and a rubbing technique" (Driver and Masey 1957:243). Driver and Masey suggest that more moist climates produce fruits, nuts, and tubers that could be processed with wooden facilities and implements such as wooden mortars and pestles.

Cross-cultural data reveal that manos and metates were utilized to process a variety of wild plant products. This information is summarized in Table 58. As we see, much of the ethnographic information regarding aboriginal use of grinding or milling stones deals with Australian hunter-gatherers. These ethnographic accounts offer valuable descriptions of wild plant collecting, processing, and cooking. Such ethnographic accounts deal with plant resources — particularly grass seeds, e.g., *Panicum* — that are similar to food resources consumed in the American Southwest and the Great Basin. Although we must be very careful in our use of ethnographic analogies, we believe that these descriptions of aboriginal activities can provide clues regarding the interrelationships between tools and behavior. Such interrelationships can then be operationalized and tested using archeological data in the American Southwest.

A number of anthropologists (e.g., Allen 1974; Cane 1987; Kirk 1981; Tindale 1974) have discussed the consumption of grass seeds by aborigines in the Northern Territory and the Western Desert regions of Australia. Tindale (1974, 1977) has pointed out that plant food resources are processed either wet or dry by

grinding stones. Acacia seeds, fruit pulp, and fig kernels, for example, are processed dry on grinding stones. Grass seeds such as panic grass (*Panicum* sp.) are generally processed wet. Wet-ground grass seeds are referred to as "damper" in the Australian literature.

Tindale (1974:105) provides the following description of wet grinding:

> Women gather the heads of grass with the ripening ears while they are still green, and stacked them inside a brush enclosure which was then fired. The women turned the pile with poles to shake out the parched seeds that were then piled on opossum skin rugs. Men threshed the seeds and removed the husks by trampling then in a rectangular hole in the ground. Other men worked a stick around in a circular hole filled with the trampled grain. This caused the husks to work their way to the top of the pile. Further winnowing and the use of bark dishes called ('wiri) and an especially large canoe-shaped bark vessel known as a jubbil ('jub:il) completed the operation of cleaning the grain, which was then stored in skin bags until needed. Then the grain was prepared for eating by wet-grinding on millstones called ('dajurl) and making flat cakes, cooking them in ashes of a fire.

Allen (1974) presents several additional descriptions of this same process of collecting, processing, storing, and consuming various kinds of grass seeds in Central Australia and New South Wales. These ethnohistorical descriptions of grass seed processing refer repeatedly to swept or bedrock threshing floors, fires for parching green seeds, brush pile "drying racks," winnowing trays, manos and metates, stone harvest knives, skin storage bags, and seed cakes baked in ashes. Several ethnohistoric or ethnographic accounts refer to the short period of time that ripe grass seeds were available for harvest. Aborigines had to compete with animals for the ripened seeds. And, in addition, the brittle rachis of a ripe seed allows much of the seed to fall to the ground. If ripe grass seeds drop from the plants, collecting costs increase, or the task becomes impossible (Allen 1974:313-317). On the other hand, unripe grass seed can be expected to contain fewer calories and/or grams of protein.

With the domestication of maize, these general distributional patterns were maintained more as a function of aboriginal maize processing techniques. Driver and Massey (1957:243) emphasized that hard flint varieties stored better in the humid eastern regions of both continents. The softer flour varieties could be stored successfully in the more arid regions such as the American Southwest. Use of stone grinding implements was continued in this region after the adoption of maize. Trough and/or slab metates in milling bins were used in the American Southwest to process great quantities of maize meal for preparing piki bread.

Archeologists are increasingly devoting more attention to the study of ground stone tools — particularly grinding implements, e.g., mortars, manos, and metates. Recent studies in archeology and anthropology that are grounded in optimal feeding strategies have made it very clear that plant foods require greater processing costs than animal foods (see Hawkes and O'Connell 1981; Symms 1984a). Cane (1987:401) points out, for example, that aborigines in Western Australia spend approximately one hour grinding 200 grams of grass seed on a stone slab. This grass seed contains an average of 277.5 kcal/100 grams (uncooked) or 381.11 kcal/100 grams (cooked "damper"). Therefore, the caloric yield for one hour of seed grinding ranges from 555 kcal to 762.21 kcal. This processing cost is very high for an adult female who would have to spend 13 to 18 hours each day grinding grass seed sufficient to feed a family of four. We might expect, then, that such high grass seed processing costs would limit hunter-gatherer dependence on such foods. Grass seeds and similar grains could only constitute a limited proportion of the total dietary requirements. Dependence on such resources could only increase as a function of more time-minimizing shifts in food processing technology. Kane's (1987) plant processing data for the Western Australian aborigines indicates that the grinding of grass seeds (e.g., *Panicum*, *Fimbristylis*, and *Chenopodium*) constitutes approximately 45 percent of total plant food processing time.

Such quantitative studies enable archeologists to assign significance to prehistoric shifts in the use of ground stone tools used for plant processing. Archeologists must develop a number of alternatives for assessing

the function of such implements (see Grady 1980; Adams 1986, 1988). Archeologists working in the American Southwest have generally assumed that manos and metates reflect primary dependence on maize, particularly in post-Basketmaker ground stone assemblages. This assumption is not justified in many instances, given recent assessments of the variability of Anasazi diet (e.g., Effland et al. 1981; Powell 1983; Sullivan 1986; Wetterstrom 1986).

Table 49. Descriptive statistics for complete manos, N = 19.

	Maximum length (cm)	Maximum width (cm)	Maximum thickness (cm)	Weight (g)	GSA1 (cm^2)	GSA2 (cm^2)
Mean	13.13	9.03	4.03	716.24	103.98	87.48
Minimum	7.50	6.90	1.50	115.40	36.00	27.95
Maximum	19.00	10.90	6.60	1453.40	205.20	169.29
Range	11.50	4.00	5.10	1338.00	169.20	141.34
s.d.'	2.78	1.05	1.40	344.17	41.06	34.98
C.V.	0.21	0.12	0.35	0.48	0.39	0.40

s.d.' – sample standard deviation; C.V. – coefficient of variation.

Table 50. Descriptive statistics for incomplete manos, N = 33.

	Maximum length (cm)	Maximum width (cm)	Maximum thickness (cm)	Weight (g)	GSA1 (cm^2)	GSA2 (cm^2)
Mean	8.29	6.46	3.34	282.85	45.08	23.13
Minimum	1.60	1.30	0.70	1.90	2.08	-----
Maximum	17.70	10.80	5.70	931.10	136.00	84.60
Range	16.10	9.50	5.00	929.20	133.92	-----
s.d.'	2.97	2.17	1.21	201.01	28.76	-----
C.V.	0.36	0.34	0.36	0.71	0.64	-----

s.d.' – sample standard deviation; C.V. – coefficient of variation.

Table 51. Descriptive statistics for ovoid manos, N = 8.

	Maximum length (cm)	Maximum width (cm)	Maximum thickness (cm)	Weight (g)	GSA1 (cm^2)	GSA2 (cm^2)
Mean	11.25	8.89	4.15	671.77	80.38	76.57
Minimum	9.90	6.90	2.50	382.60	36.00	44.66
Maximum	13.60	10.70	6.00	1349.50	123.90	100.80
Range	3.70	3.80	3.50	966.90	87.90	56.14
s.d.'	1.26	1.12	1.14	324.49	27.70	19.75
C.V.	0.11	0.13	0.27	0.48	0.34	0.26

s.d.' – sample standard deviation; C.V. – coefficient of variation.

Table 52. Descriptive statistics for oblong manos, N = 10.

	Maximum length (cm)	Maximum width (cm)	Maximum thickness (cm)	Weight (g)	GSA1 (cm^2)	GSA2 (cm^2)
Mean	15.19	9.33	4.02	796.31	127.79	94.76
Minimum	13.20	7.60	1.50	115.40	72.15	27.95
Maximum	19.00	10.90	6.60	1453.40	205.20	169.29
Range	5.80	3.30	5.10	1338.00	133.05	141.34
s.d.'	1.69	0.85	1.69	352.31	37.16	41.82
C.V.	0.11	0.09	0.42	0.44	0.29	0.44

s.d.' – sample standard deviation; C.V. – coefficient of variation.

Table 53. Frequencies of complete and incomplete manos according to shape or outline.

Shape	Complete	Incomplete
Rectangular	1	5
Ovoid	8	6
Oblong	10	2
Irregular	1	21
Total	20	34

Table 54. Frequencies of complete and incomplete manos according to cross section.

Cross Section	Complete	Incomplete
Tabular	0	6
Biconvex	11	14
Plano-convex	5	0
Wedge	3	6
Indeterminate	1	8
Total	20	34

Table 55. Attributes for complete metate specimens.

Specimen	Maximum length (cm)	Maximum width (cm)	Maximum thickness (cm)	Weight (g)	GSA1 (cm^2)
146-16	33.00	32.80	3.50	6000	942.24
147-44	45.70	25.40	7.00	—	872.49
165-46	50.80	34.30	7.00	—	619.76
166-36	50.80	38.10	7.00	—	622.23
Mean	45.07	32.65	6.12		764.18

Table 56. Descriptive statistics for incomplete metates, N = 56.

Specimen	Maximum length (cm)	Maximum width (cm)	Maximum thickness (cm)	Weight (g)	GSA1 (cm^2)
Mean	15.50	11.21	2.99	945.76	125.89
Minimum	5.00	2.10	0.60	26.40	12.96
Maximum	33.00	29.20	6.80	4336.30	625.00
Range	28.00	27.10	6.20	4309.90	612.54
s.d.'	6.99	6.03	1.27	1074.16	135.57
C.V.	0.45	0.54	0.43	1.14	1.08

s.d.' – sample standard deviation; C.V. – coefficient of variation.

Table 57. Results of pollen washes for metates from 42SA16858.

Specimen Number	Cheno-Ams	Cleome	Ephe-dra	Gram-ineae	Opun-tia	Plan-tago	Shep-herdia	Typha	Zea mays
T172-31E	-	X	-	-	-	-	-	-	X
T172-29E	X	-	-	X	-	-	-	-	X
T166-36[1]	X	-	-	X	-	-	-	-	X
T165-37[2]	X	X	X	X	-	X	-	X	-
T173-19[3]	X	-	X	X	-	X	-	-	X
T147-44	-	-	X	X	X	X	-	X	-
T165-46	X	-	-	-	-	X	X	-	-
T173-48	-	X	X	X	X	X	-	-	-
Total cases	5	3	4	6	2	5	1	2	4

[1] Also contained Liguliflorae pollen.
[2] Also contained Leguminosae and Solanaceae pollen.
[3] Also contained Liguliflorae pollen.

Table 58. Cross-cultural data regarding the use of grinding stones.

Aboriginal Group	Location	Use	Reference
Modoc	N. California	fish, meat, water lily seeds	Kroeber 1928
Koso-Shoshonean	California	pine nuts, desert sand grass, and Mormon tea	Kroeber 1938
Cahuilla	S. California	wild seeds, sage, shadscale, wild seeds	Kroeber 1928
Kamia	S. California	"swamp food," shadscale, mesquite	Kroeber 1928
Havasupai	N. Arizona	wild seeds, pine nuts	Smithson 1959
Cahita/Yaqui	S. Arizona	mesquite	Beals 1945
Wahiro	N. Mexico	amaranth seeds, roots, Acacia seeds	Gentry 1963
Seri	Tiburon Is.	mesquite beans, prickly pear seeds	McGee 1898
Bagundji	New South Wales, Australia	panic grass seed, salt bush seed, flax, acacia seeds	Allen 1974
Iliaura	N. Territory, Australia	panic grass seed, chenopodium	Tindale 1974
Karawa	N. Territory, Australia	yams, cycad nuts	Tindale 1974
Pitjanjara	N. Territory, Australia	panic grass, pigweed, portulaca	Tindale 1974
Wadjari	W. Australia	Acacia seeds, figs, grass seed	Tindale 1974
Maiwali	Queensland, Australia	cycad nuts, eucalyptus seeds	Tindale 1974

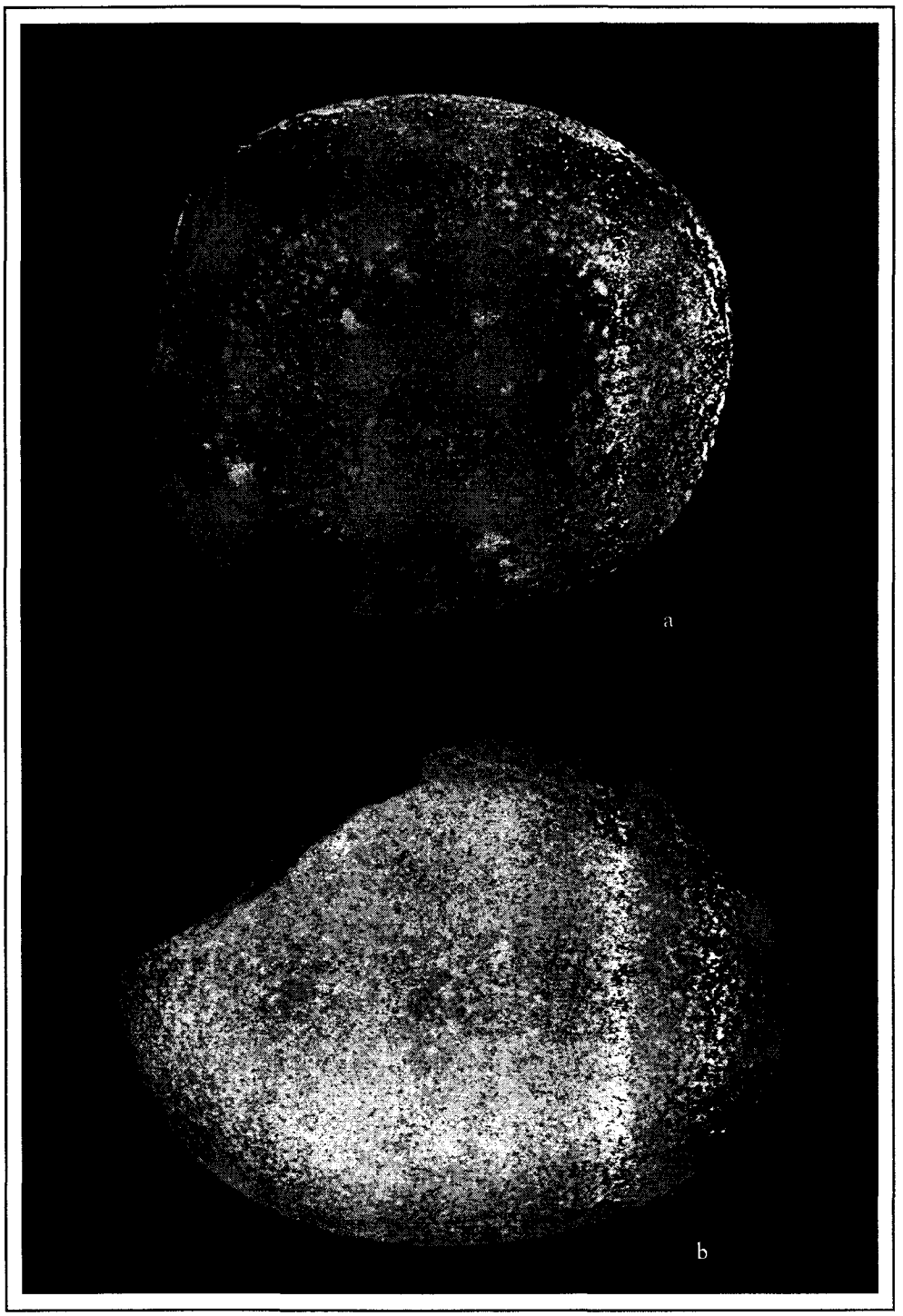


Figure 94. One-hand cobble manos exhibiting minimal shaping.

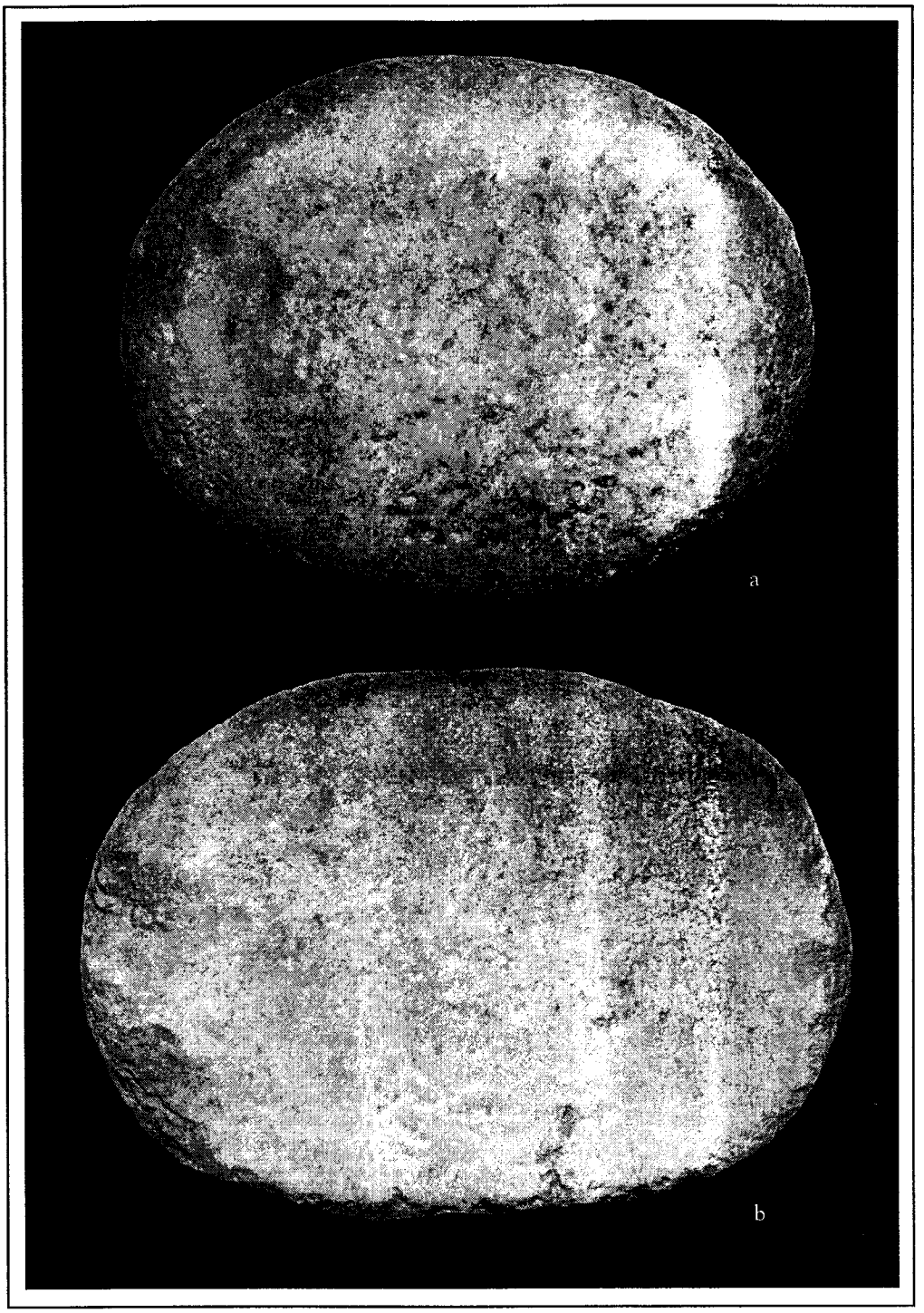


Figure 95. One-hand cobble manos.

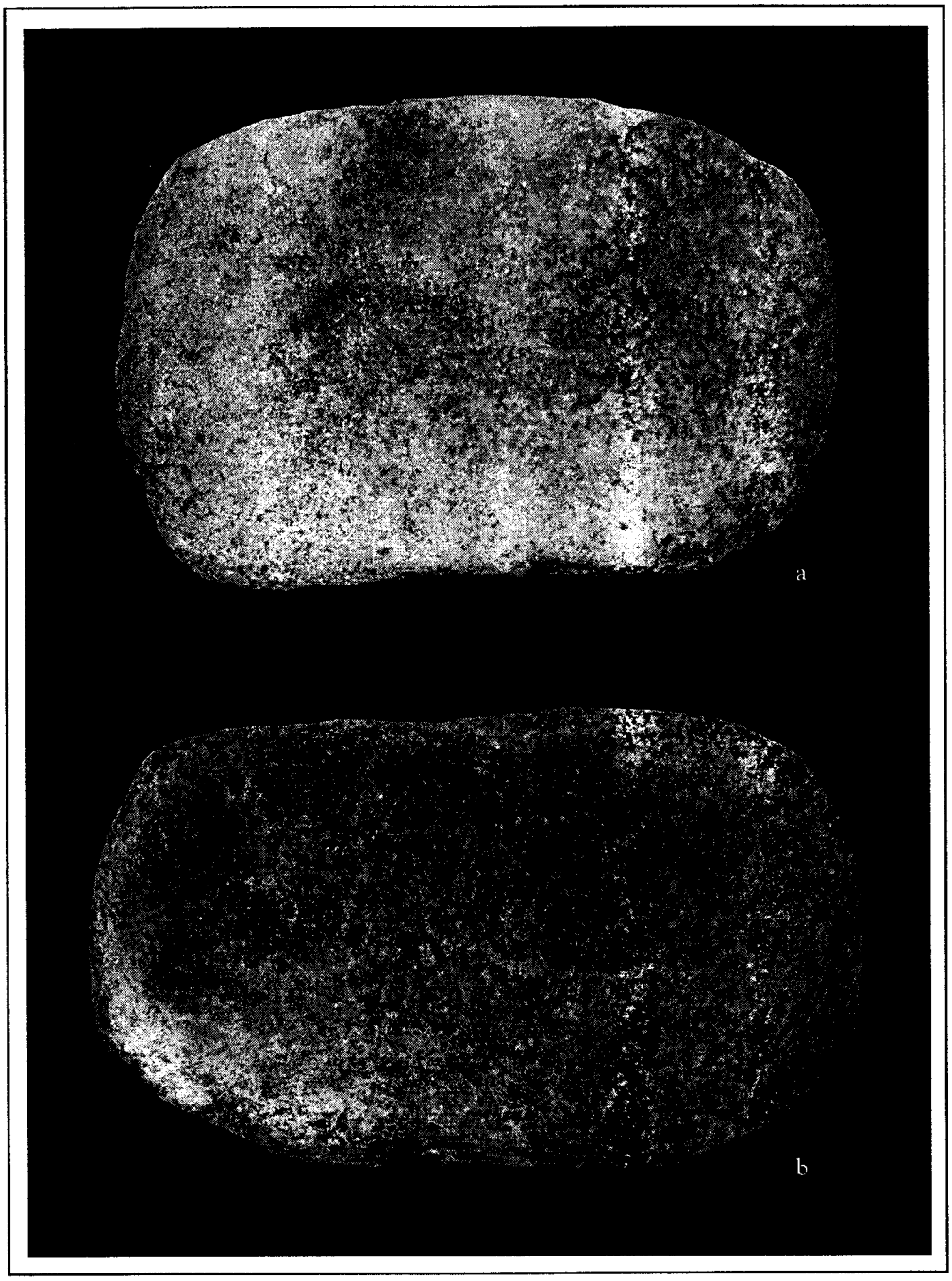


Figure 96. Two-hand manos.

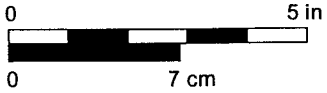
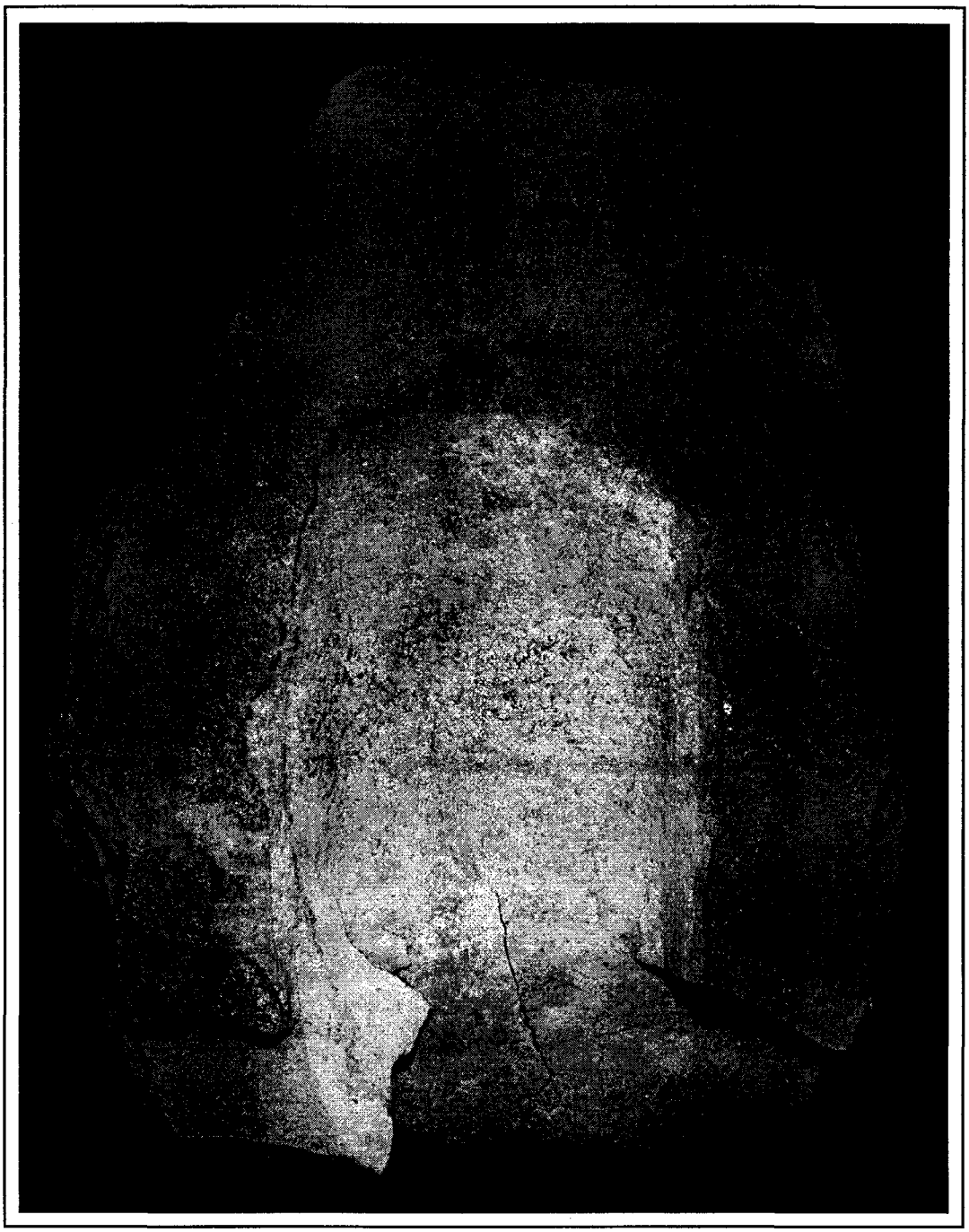


Figure 97. Shallow trough metate from Gray's Pasture (42SA16858).



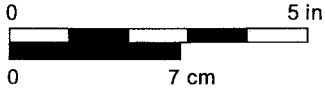


Figure 98. Deep trough metate from Gray's Pasture (42SA16858).

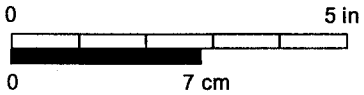
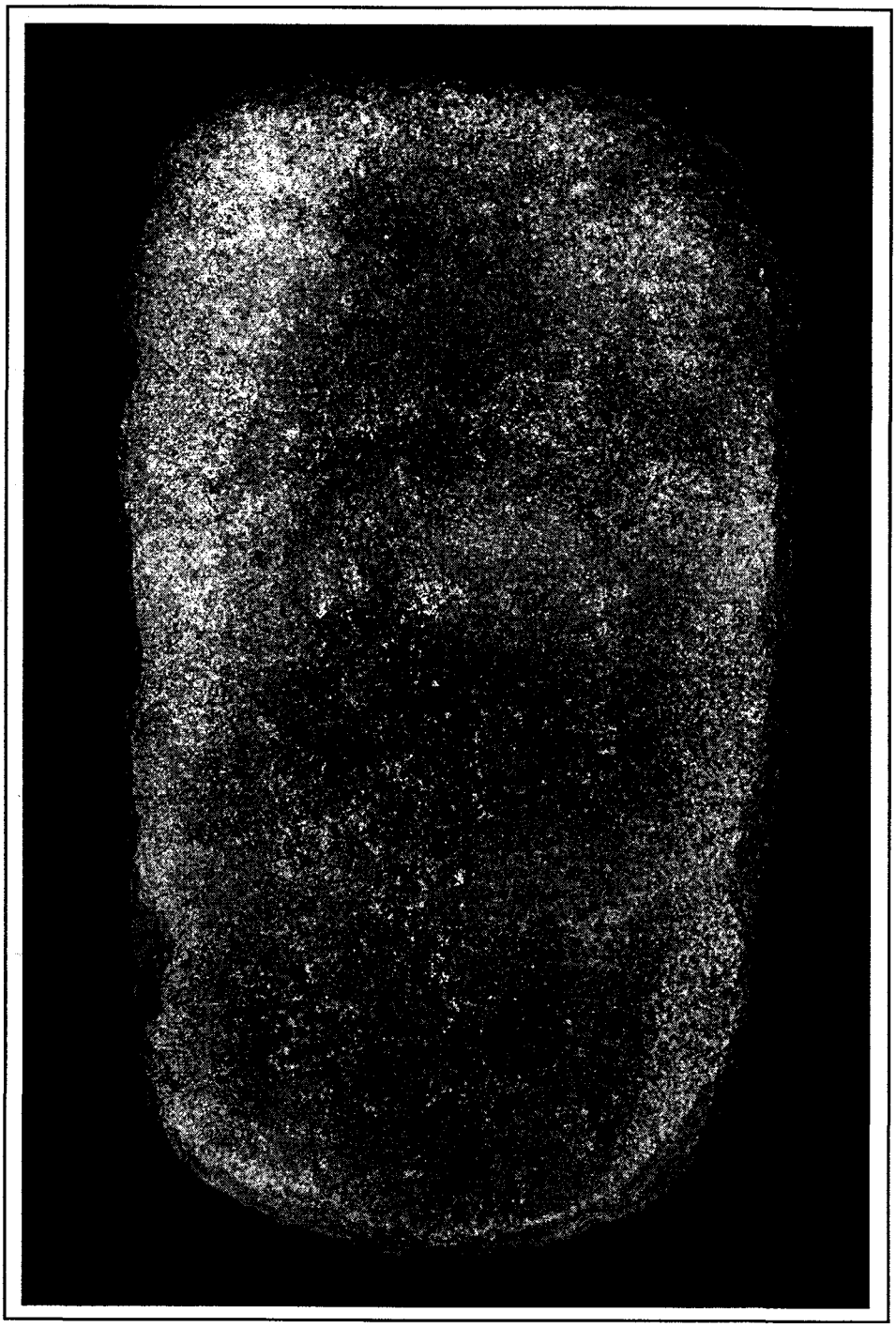


Figure 100. Unshaped slab metate.



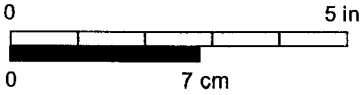


Figure 99. Shaped slab metate for use in milling bin from Gray's Pasture (42SA16858).

CERAMIC ASSEMBLAGE

INTRODUCTION

A number of archeologists would suggest that studies of prehistoric ceramics have dominated previous investigations of Southwest prehistory.

For example, Woodbury and Zubrow (1979:53) state,

> The introduction of pottery making to the Southwest has probably been overemphasized by archaeologists because of its importance to them, as a basis for their study of prehistory. It can be made in so many varying ways, each detail culturally determined, that it is an ideal clue to determining the spatial and temporal relationships among its makers, as a means of constructing basic culture-historic frameworks by which other data from the past may be placed in context. It has played a major role in the relative dating of archaeological sites and in defining regional and local subcultural units. Therefore, it has received attention as an archaeological tool of investigation far beyond its importance as an aspect of prehistoric technology, economics, or even art.

Prehistorians throughout this century have concentrated on the "objectification" of mental templates that were thought to have governed the manufacture and decoration of aboriginal ceramic vessels. Morphological and decorative variation in such ceramics has been utilized as a material correlate or empirical index of cultural distance. Despite this sociocultural emphasis, archeologists have devoted little attention to the contexts in which vessel shape, color, surface treatment, patterns, and use served to convey information regarding genetic distance and/or local and regional socio-economic and socio-political affiliation(s). There are notable exceptions to this generalization (e.g., S. Plog 1980).

Technological characteristics of prehistoric ceramics have been examined and described in detail in the American Southwest; yet such analyses have been primarily designed, as Woodbury and Zubrow (1979) have pointed out, to define more than 900 pottery types. Discussion of the underlying functional bases for ceramic vessel construction, composition, formal variation, and use life has recently become the focus of a number of significant studies (e.g., Braun 1980; Brown 1989; Nelson 1981, 1985; M. Smith 1983, 1985, 1988).

ADAPTIVE SIGNIFICANCE OF PREHISTORIC CERAMICS

Binford (1980, 1982, 1983a) did not examine horticultural adaptations in the research discussed above. However, one might suggest that the forager-collector continuum might be extended to encompass aboriginal groups that became more dependent on domesticated plants. In general, such groups would have been more dependent on select plant resources, food storage, and logistical mobility strategies than collectors. Binford (1980:18) states, "We would therefore tend to expect some increase [in logistically organized procurement strategies] associated with shifts toward agricultural production." Increased dependence on carbohydrate-rich plants, particularly cereals in this case, would favor collapsed home ranges based on energy needs. A major reduction in residential mobility is frequently associated with decreased home range size, regional packing, and the emergence of territoriality (Binford 1982, 1983). On the other hand, logistical mobility related to animal protein procurement may increase dramatically in areas that lacked domesticated animals.

Reduced residential mobility and heavy dependence on carbohydrate-rich food resources would also be associated with changes in adult female body composition and reproductive physiology and associated increases fertility and population growth rates. In the arid Southwest, aboriginal food production based on cereal crops (i.e., maize) would have intensified time constraints on labor required for field preparation, planting, weeding, and harvesting. As Schalk (1977) points

out, the implementation of a specialized food storage strategy shifts environmental and organizational stresses from times of food scarcity to times of food abundance. With cereal horticulture, however, such labor organization stresses coincide with the growing season, but precede the actual period of food abundance. Large quantities of food have to be planted, tended, and harvested within discrete, relatively short periods of time. Furthermore, heavy dependence on food production and a more specialized diet based on carbohydrate- or oil-rich plants require significant and dramatic increases in processing costs (Ember 1983; Howell 1986:183-185).

Like collectors, horticultural groups would be expected to occupy residential sites for greater portions of the annual cycle. Such sites would be expected to contain a number of more permanent residential structures and storage facilities. Initial horticultural commitments would have been managed at the household level. Increased labor demands for cereal horticulture could have been met by adoption of a "household extending strategy" that would have served to recruit adult producers into the domestic labor force. Given this response to labor stress, food production, storage, and consumption can still be handled at the household level among closely related kin.

ADOPTION OF CERAMIC TECHNOLOGY

Many anthropologists and archeologists have assumed that ceramic vessels were not used by mobile hunting and gathering peoples (Rafferty 1985). Rafferty (1985:133-134) points out that 42.5 percent of the mobile societies in Murdock's standard sample manufactured and used ceramic vessels. In addition, forty percent of the same sample of 150 ethnographic societies that were not dependent on agriculture made use of ceramics. A chi-square test for both sets of Rafferty's (1985) data reveals that pottery making and sedentary lifestyle are significantly associated (chi-square = 18.47; df = 1; two tailed test, $p < .001$). Furthermore, pottery making and agriculture are significantly associated (chi-square = 24.38; df = 1; two tailed test, $p < .001$). However, we find that phi coefficients are low, and equal 0.35 and 0.40, respectively. These correlation coefficients suggest that less than 15 percent of the variability in the observed use of ceramics can be accounted for in terms of mobility or dependence on agriculture. Archeologists can, therefore, expect to observe a broad range of variability in the manufacture and utilization of ceramic vessels among foragers, collectors, and horticulturalists.

Braun (1983) has proposed that ceramic vessels became very important during the Late Woodland period for heating carbohydrate-rich starchy plant foods. He (1983:116) states, "Both the palatability and digestibility of starchy seeds can be enhanced by cooking them to the point of gelatinization in a liquid broth."

Hargrave and Braun (1981:12) point out that external heat sources would ultimately affect the boiling time and consistency; so, "Consequently, we may expect that an increasing importance of starchy broths would ... involve increasing levels of heat intensity and greater rates of temperature change in the use of cooking jars."

Braun (1983) discusses three significant trends in the character of prehistoric ceramic vessels during the Woodland period (ca. 600 B.C. to A.D. 900). These three trends include: (1) decreased wall thickness; (2) decreased size and density of temper particles; and (3) a shift from flat-based cylindrical to globular vessel shapes. All of these changes in vessel construction are seen to be systematically linked to "... an increasing attention to the extraction of digestible nutrition from starchy seed foods through cooking—presumably through simmering or boiling rather than parching or popping ..." (Braun 1983:119).

Such increased emphasis on cooking wild, as well as domesticated, plant seeds and nuts can be explained in terms of food processing and is essential for several reasons. First, boiling seeds, roots, and nuts facilitates mastication and enhances their palatability and digestibility (cf. Braun 1983). Crapo (1985:104) points out that, "... Cooking swells the starch within the cell, bursting the cell wall [of raw foods], and potentially makes the starch more available for digestion." Furthermore, "some foods contain natural amylase inhibitors that may be inactivated by cooking or other aspects of food processing or preparation."

Second, cooking destroys heat sensitive toxic compounds contained in many wild and domesticated plants. Such toxins include oxalates, phytates, polyphenols (e.g., phenolic acid, tannins, and flavanoids), and

lectins (Abrams 1979; Heizer 1981; Lieberman 1987). Many of these anti-nutrients decrease the rate of carbohydrate and protein metabolism. Various cooking methods, including boiling and roasting, can serve to destroy the inhibitory effects of anti-nutrients. These cooking processes may also destroy highly toxic mycotoxins in seed and nut crops produced by fungal growth. Legumes, for example, contain lectins "... that cause red blood cells to agglutinate and can destroy the walls of intestines, leading to decreased nutrient absorption" (Lieberman 1987:249). Maize contains phytates that chemically bind with trace metals such as iron, zinc, magnesium, and copper and render them unavailable to human metabolism. Both lectins and phytates are broken down by cooking.

Ceramic vessels have also played a significant role in the alkali processing of maize in the New World. Katz et al. (1975) have demonstrated a strong correlation between high levels of maize consumption and alkali treatment throughout the New World. This method involves soaking, heating, and decanting a mixture of maize, water, and lime. This processing treatment softens the maize kernel, modifies the amino acid balance, and adds calcium, phosphorus, potassium, copper, magnesium, and zinc to the solid product nixtamal. Osborn (1987, 1988) has argued that shell-tempered ceramic vessels used by prehistoric Mississippian peoples in eastern North America served to alkali-process maize. In addition, alkali treatment and heating also destroys extremely poisonous mycotoxins in maize crops attacked by fungi (Osborn 1987, 1988). Detoxification of toxic compounds in wild and domesticated plant resources, as well as contaminants such as mycotoxins, is a significant research problem that should receive further attention.

The evolutionary development of ceramic cooking and storage vessels may also be closely tied to human demography. Several investigators have suggested interrelationships between increased consumption of carbohydrate-rich plant resources, decreased residential mobility, shifts in cooking methods (including use of ceramic or metal vessels), and supplemental feeding of weanling infants (e.g., Binford and Chasko 1976; Buikstra et al. 1986:540; Lee 1980:343-344).

Binford and Chasko (1976:138-139) provide the following provocative comments:

> Ceramics is commonly added to the archaeological assemblage in the context of sedentism and is demonstrably associated with a diet characterized by small food packages and the use of stored foods. Although not well understood, the appearance of ceramics, the implied increase in the consumption of boiled foods, and trends in sedentism are commonly linked. In situations with increased consumption of boiled foods linked to increasing intensification of female labor in food procurement, the depressant effects of the latter might be prevented through increased division of labor with respect to child care. Namely, with boiled foods an elderly woman or man could feed children in the absence of their mothers, therefore obviating the disadvantages of having children closely spaced and of necessity with the mother at all times. Thus, other things being equal, we might expect increased rates of population growth in response to increased realized fertility to follow the adoption of ceramics and attendant increases in boiled foods, even with increased female participation in food-procurement activities.

ISLAND-IN-THE-SKY CERAMIC ASSEMBLAGE

A total of 2,367 ceramic vessel fragments were recovered from the Island-in-the-Sky. Less than four percent (3.21 percent) were collected during an intensive pedestrian survey; the remainder of the assemblage was obtained during excavations. Ceramics assigned to Mesa Verde types dominate the assemblage (Figure 101). Among the sherds with a Mesa Verde cultural affiliation, utility wares dominate whitewares at 42SA8506, while the reverse is true at 42SA16858. 42SA8506 has 356 sherds of utility ware and 235 of whiteware. 42SA16858 has 258 sherds of utility ware and 324 sherds of whiteware. 42SA8503 has no utility wares and 86 small fragments of whiteware. Figure 102 presents these data for the four sites with more than two

sherds. Corrugated body sherds predominate in the utility wares. Very few plain sherds were observed. Within the Mesa Verde Whiteware sherds at the two sites with the vast majority of the sherds, a number of vessel forms appear. Figure 103 plots bowl, jar, jar handle, olla rim, dipper, and indeterminate vessel form sherds. The number of bowl and jar sherds at 42SA8506 is relatively equal, with 112 sherds from jars and 101 sherds from bowls. In contrast, jar sherds predominate at 42SA16858, where 183 jar sherds plus the three jar handle and six olla rim sherds outnumber the 114 bowl sherds. Finally, within the Mesa Verde Whitewares, Figure 104 presents the distribution of ceramic types at each site. Late unpainted white and late carbon painted white sherds compose most of the assemblage. 42SA8506 has 22 sherds that can be identified as Mesa Verde Black-on-white and 47 sherds that can only be identified as Pueblo III Black-on-white. 42SA16858 has seventeen sherds that may be classified as Mesa Verde Black-on-white, specifically, 105 sherds that fall into the Pueblo III Black-on-white general type, and seven sherds that are McElmo Black-on-white.

42SA8506 and 42SA16858 not only had the great majority of sherds recovered, they also yielded the only complete ceramic vessels found. Five nearly complete vessels were reconstructed from sherds found at these sites. Four vessels were found at 42SA16858, including a plain miniature jar or bottle (Figure 105), two Mesa Verde Black-on-white ollas (see Figures 106 and 107), and a Mesa Verde Corrugated jar (Figure 108). An incomplete bowl from 42SA16858 is illustrated in Figure 109.

The large Mesa Verde Black-on-white olla has an estimated volume equal to 30.2 liters (Table 59). This large olla was recovered from the bottom of a narrow, cylindrical pit (Feature 40) that had been excavated at the Gray's Pasture site (42SA16858). It was broken, and mended with a pair of drilled holes and cordage (?) (see Figure 110). The single reconstructed vessel from 42SA8506 was a Kayenta Corrugated jar (Figure 111). Two of the vessels from 42SA16858, a Mesa Verde Black-on-white olla and the Mesa Verde Corrugated jar, and the Kayenta Corrugated jar from 42SA8506 were uncovered nearly intact. One partial black-on-white mug was recovered from the excavations; interestingly, the vessel fragments were found at both the Dunes site (42SA8506) and Gray's Pasture (42SA16858).

These vessels were carefully removed in the field with surrounding soil. Pollen washes from these sherds produced important information on the contents of the vessels. Pollen recovered from these washes is described in the pollen analysis section of this report. All three vessels yielded *Zea mays* pollen, as well as pollen from wild plant resources.

Volumes were estimated for five reconstructed vessels (Table 59). The volumes of these vessels were estimated through the use of volume formulae for geometric solids. Combinations or sections of common geometric forms such as spheres, cylinders, cones, or frustums described the vessel shapes. For example, the ollas approximated spheres with a spherical segment removed from their bases. The volumes of the ollas' necks were computed as cylinders. A sphere, hemisphere, spherical segment, cylinder, and frustum in various combinations described the shape of the five vessels.

Table 59. Volume estimates for reconstructed vessels.

Site	Vessel Description	Vessel Code	Volume (in liters)
42SA16858	Mesa Verde Black-on-white olla	10	19.21
42SA16858	Mesa Verde plain body miniature jar	13	0.14
42SA16858	Mesa Verde Black-on-white olla	15	30.20
42SA16858	Mesa Verde Corrugated jar	17	3.70
42SA8506	Kayenta Corrugated jar	6	1.70

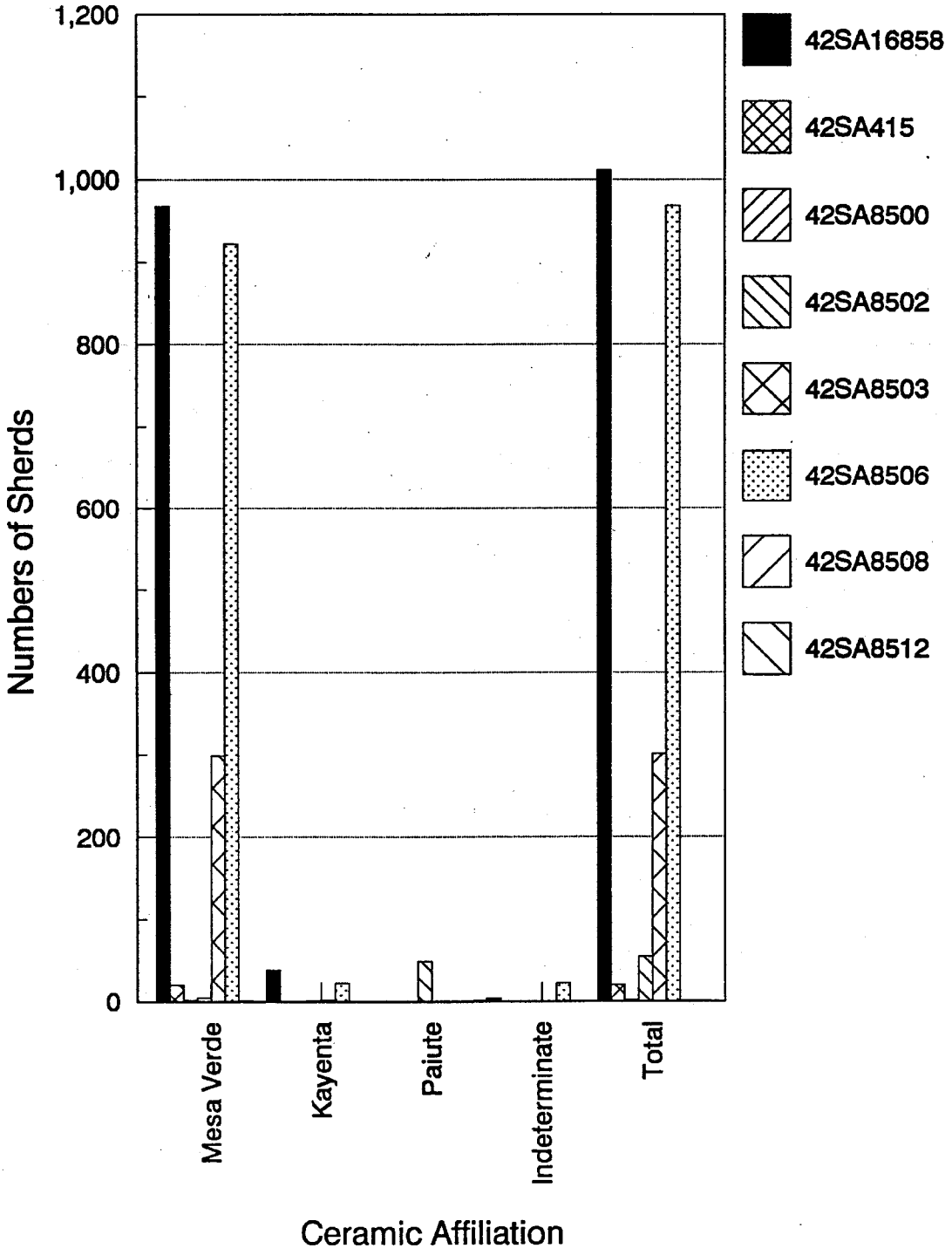


Figure 101. Ceramic affiliation by site.

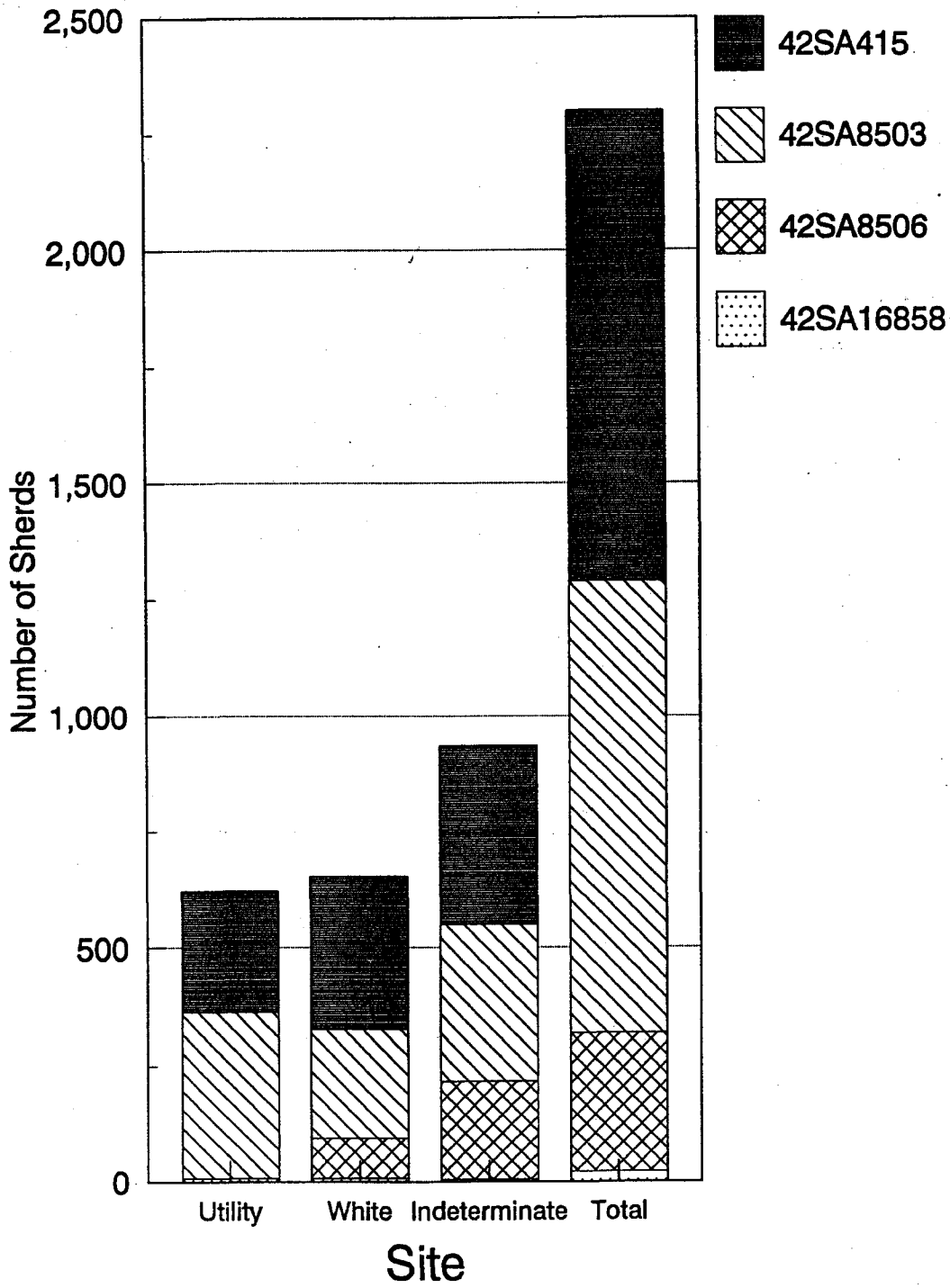


Figure 102. Mesa Verde wares for sites.

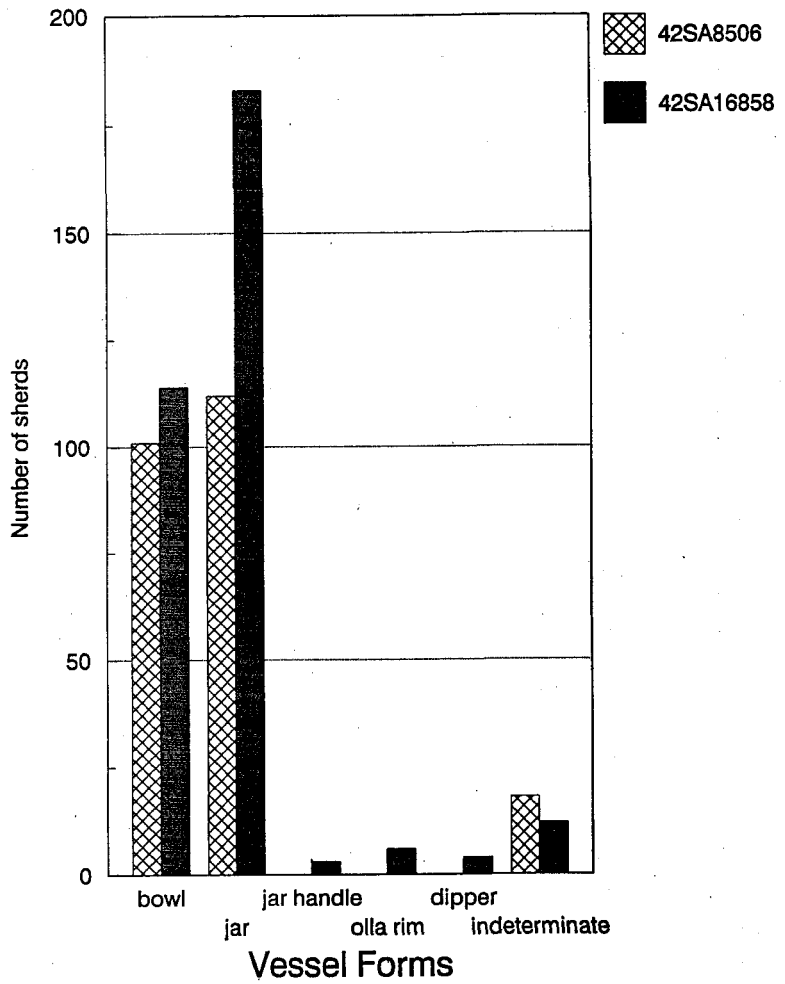


Figure 103. Mesa Verde Whiteware vessel forms.

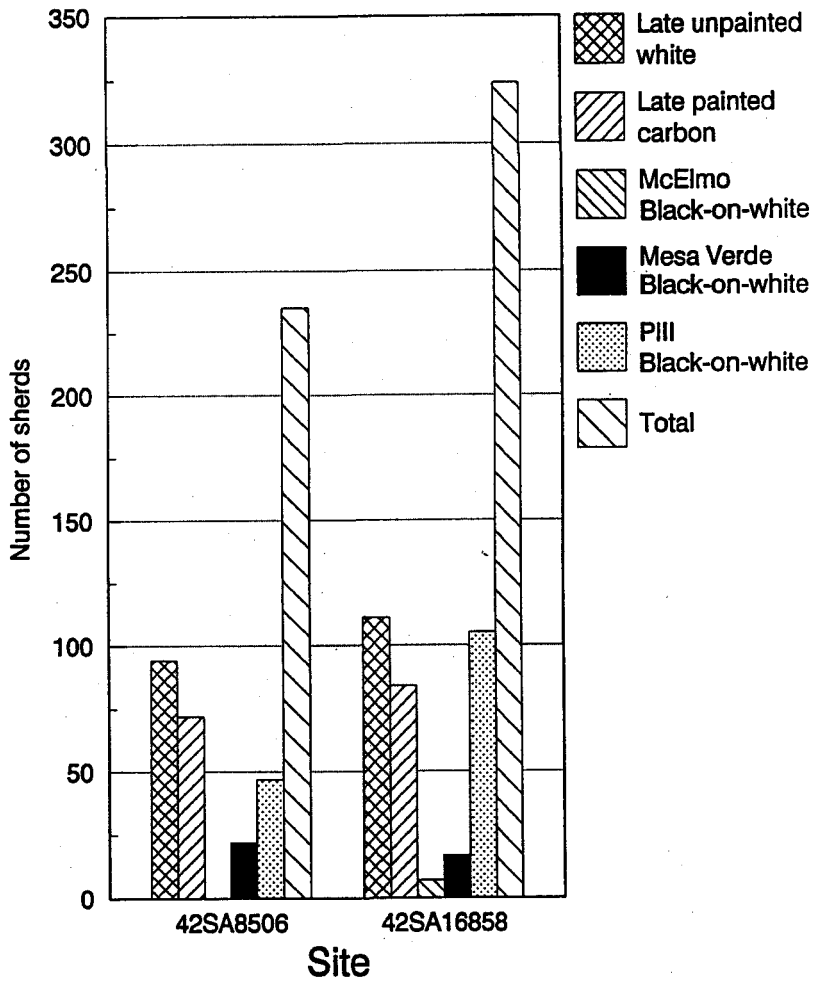


Figure 104. Distribution within site, 42SA8506 and 42SA16858, Mesa Verde Whiteware types.

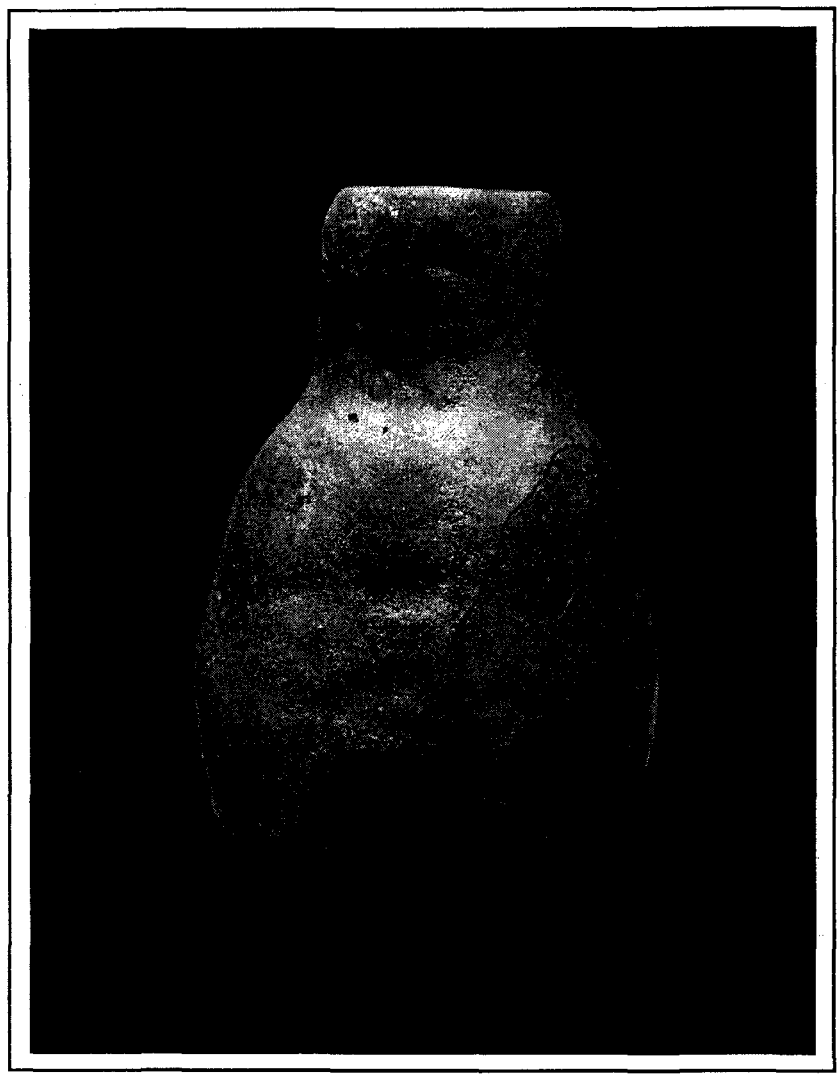


Figure 105. Small plain bottle or jar.

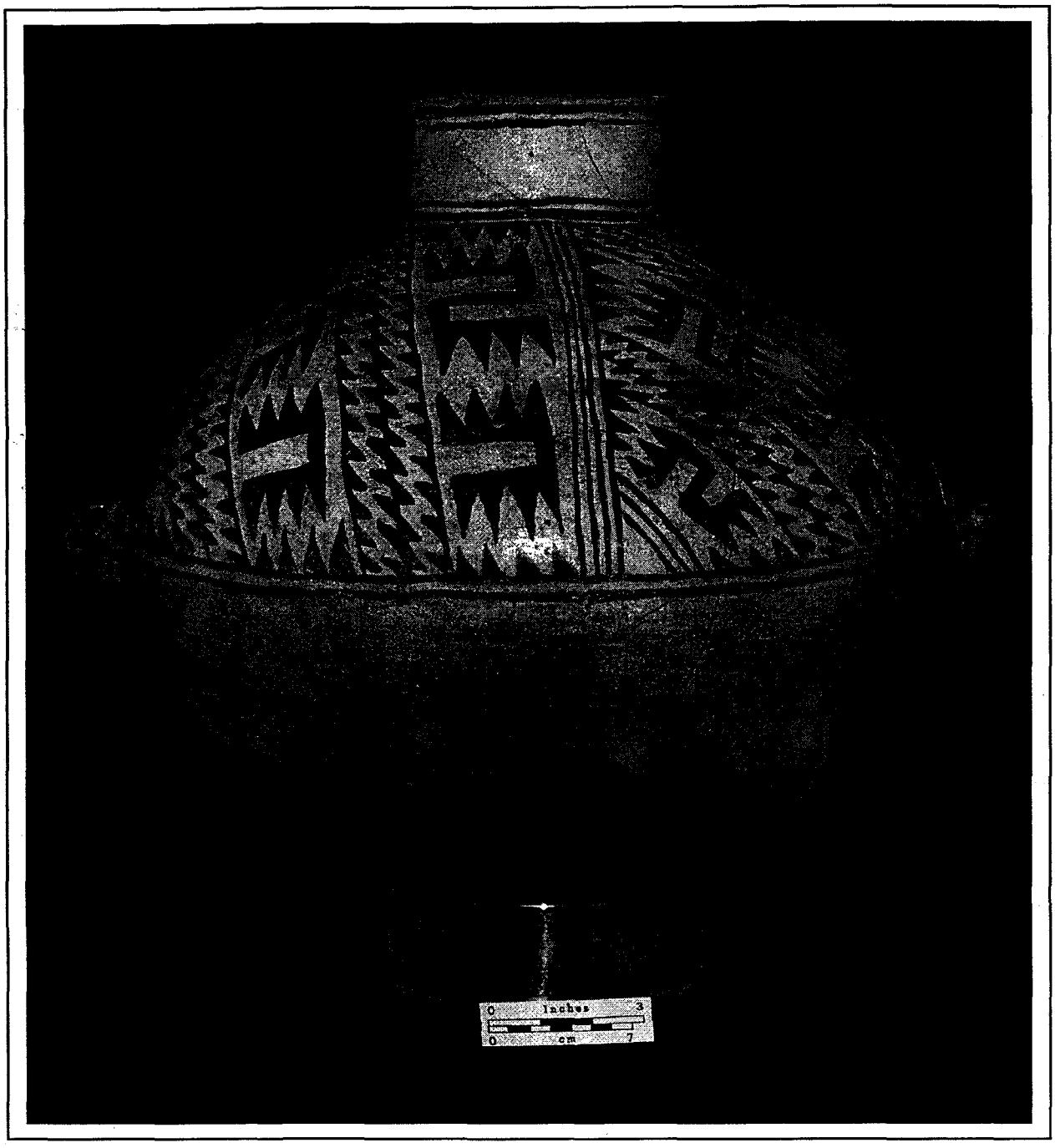


Figure 106. Mesa Verde Black-on-white olla recovered from Feature 40 at Gray's Pasture (42SA16858).

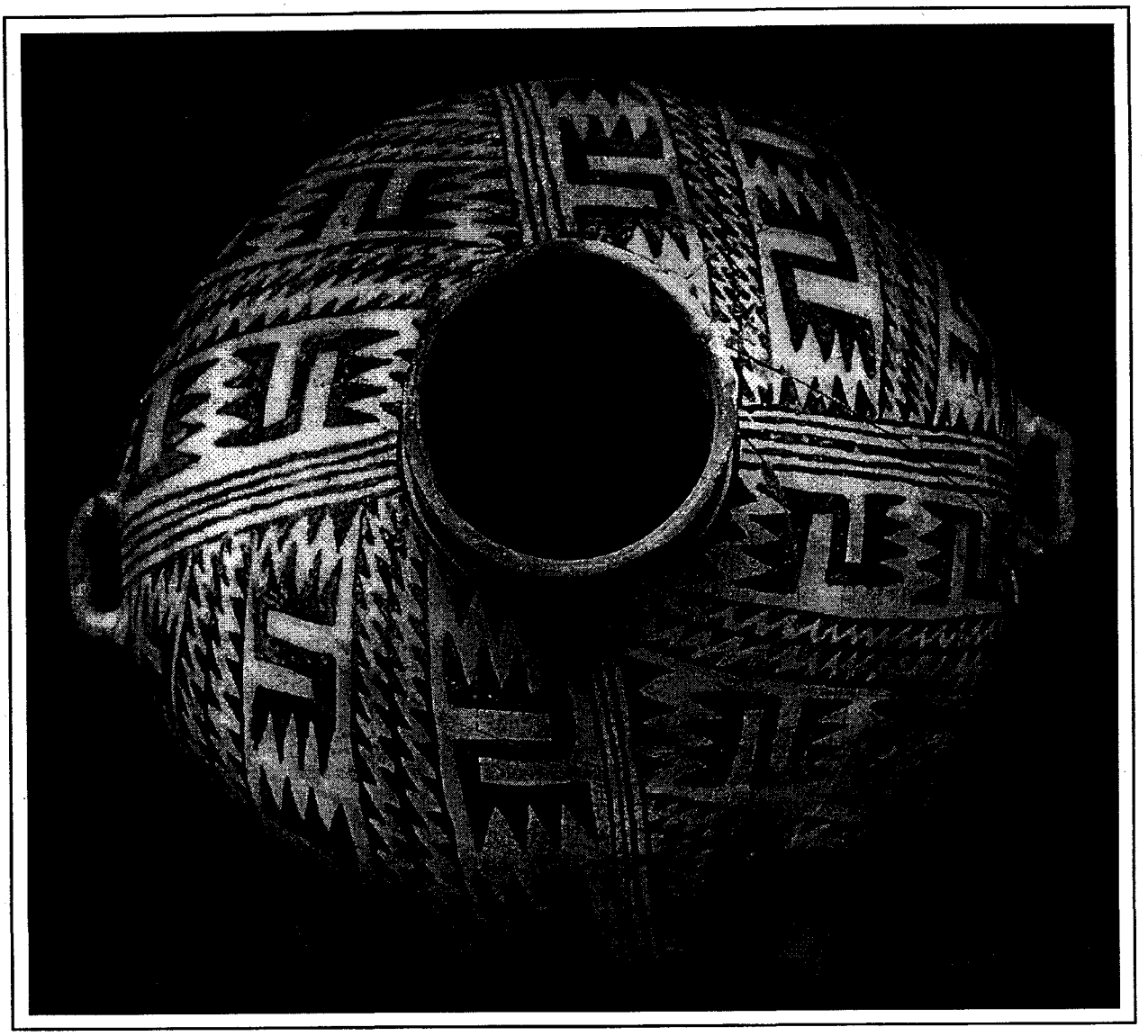


Figure 107. Design field of Mesa Verde Black-on-white olla from Gray's Pasture (42SA16858).

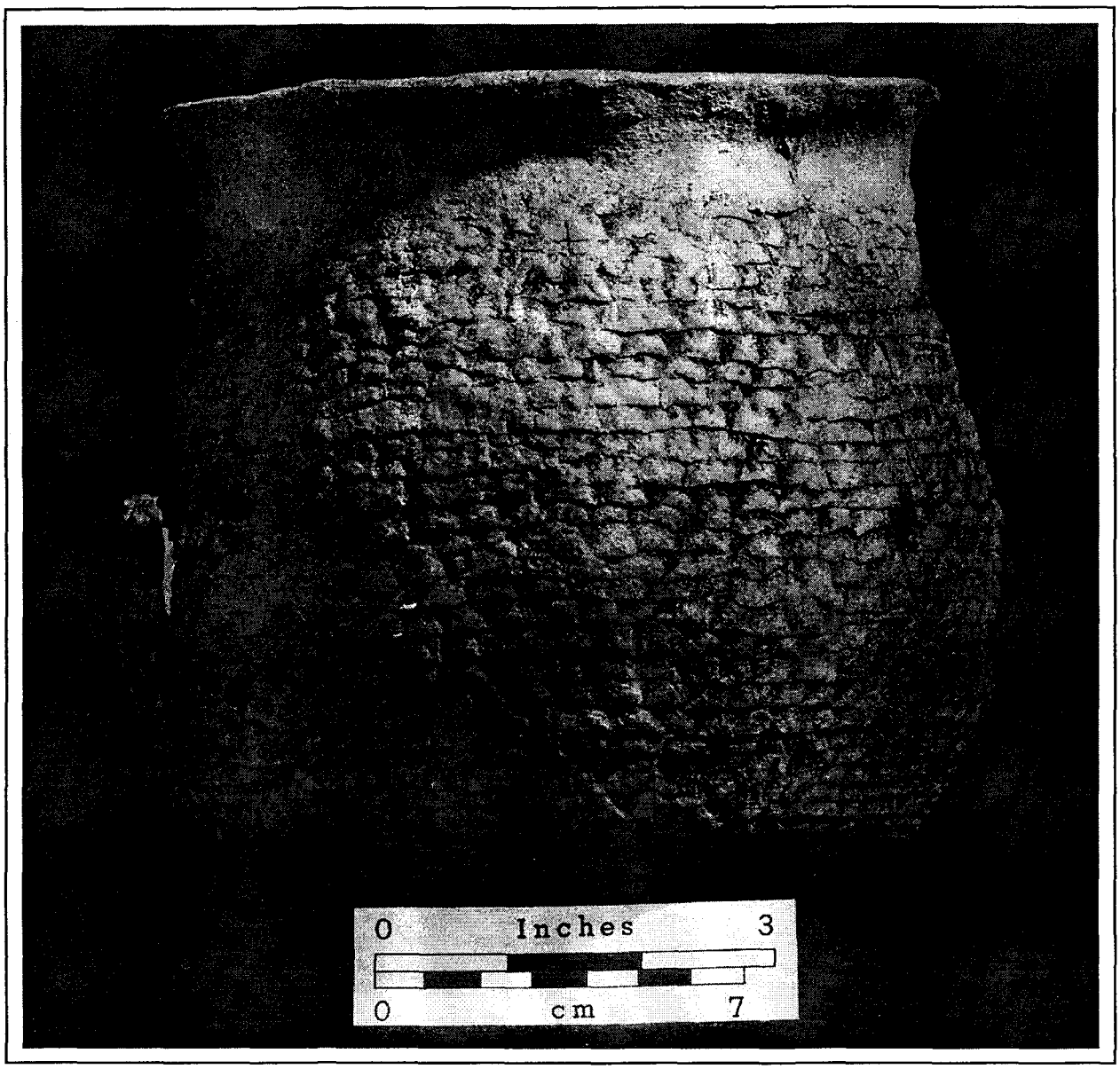


Figure 108. Mesa Verde Corrugated jar from Gray's Pasture (42SA16858).

Figure 109. Incomplete Black-on-white bowl from Gray's Pasture (42SA16858).

Figure 110. Mesa Verde Black-on-white olla from Gray's Pasture (42SA16858) showing broken base and paired mend holes.

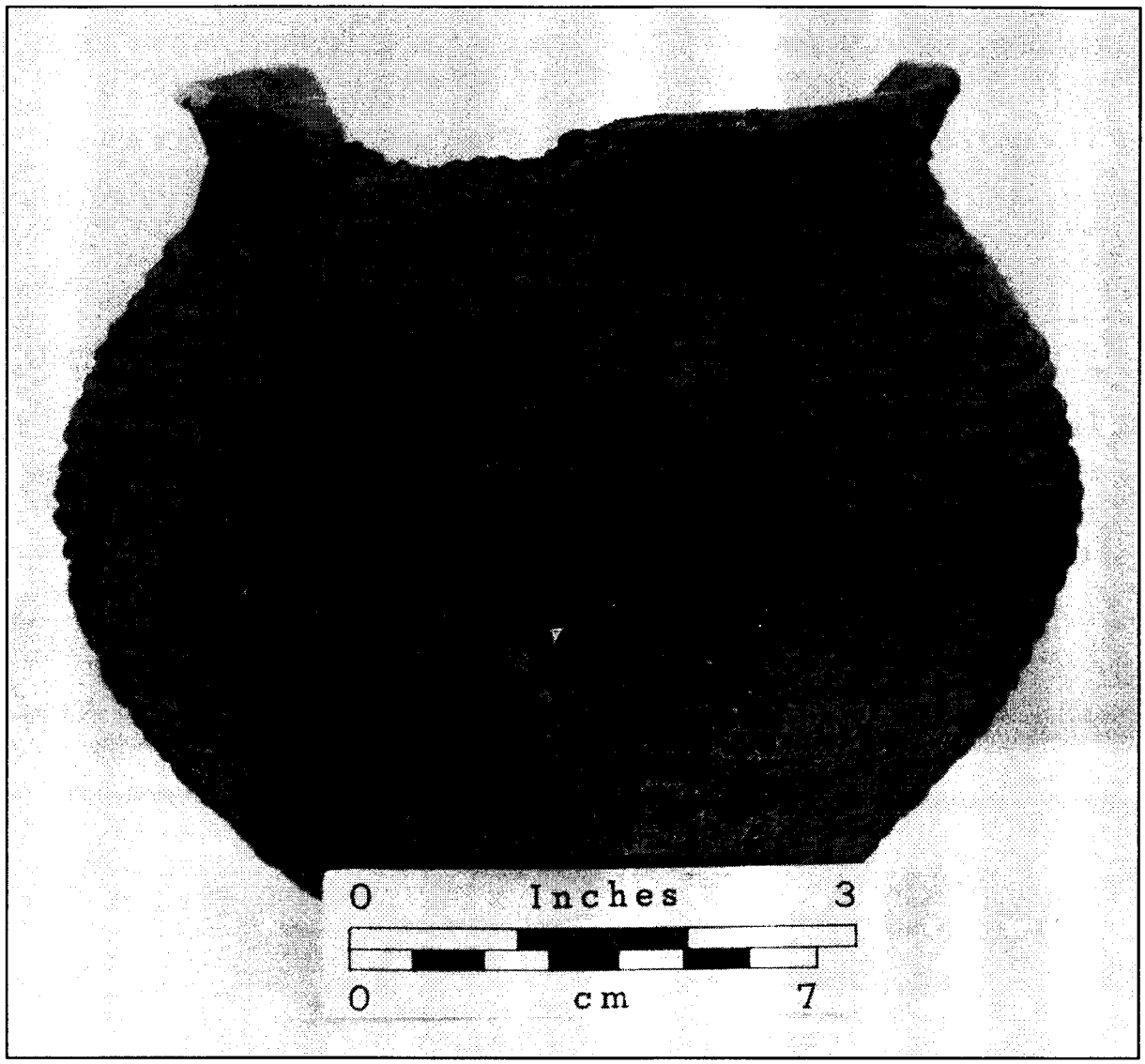


Figure 111. Kayenta Corrugated jar recovered from Feature 33 at the Dunes site (42SA8506).

ANALYSIS OF ARTIFACT ASSEMBLAGE VARIABILITY

Archeological assemblages exhibit variability in terms of size, content diversity, spatial distribution, and organizational properties. The present study is designed to focus on content diversity and spatial distribution of an artifact assemblage simultaneously. This combined measure of artifact assemblage variability, then, will be referred to as pattern diversity.

Content diversity has been measured in terms of artifact/assemblage attribute lists (e.g., Willey and Phillips 1955, 1958), cumulative graphical methods (Bordes 1950, 1961; Sonneville-Bordes and Perrot 1953), and richness-evenness-diversity measures (e.g., Budy and Elston 1986; Camilli 1983; Conkey 1980; Jones, Grayson, and Beck 1982, 1983; Kelly 1985; Kintigh 1984; Lightfoot 1985; Reher 1978; Reid 1982; Rhode 1988; Stafford 1980; Thomas 1983b, 1984; Whittlesey 1982; Wood 1978; Yellen 1977).

Since the initial development of the theoretical and methodological assumptions for our study of artifact assemblage variability, archeologists have devoted considerable attention to the investigations of archeological diversity. These more recent studies include research by Budy and Elston (1986), Kintigh (1984), McCartney and Glass (1990), Rhode (1988), and Thomas (1983, 1984, 1989). Also, an entire collection of archeological diversity papers was published by Leonard and Jones (1989).

A number of recent investigations of artifact assemblage diversity in the Pacific Northwest, the Great Basin, and the American Southwest have proposed an astounding generalization. Jones et al. (1983:65) suggest that approximately 83 percent of the variation in stone tool assemblage diversity (i.e., "richness") can be explained simply as a statistical function of sample size.

Interestingly, several initial studies by Thomas (1983b, 1984) proposed that sample size accounted for more than 90 percent of the diversity of archeological artifact assemblages from both surface and excavated materials in Monitor Valley, Nevada. Thomas (1983b, 1984) also makes the same argument for artifact assemblage diversity reflected in 16 horizons at Gatecliff Shelter and 10 additional excavated assemblages from the Monitor Valley in Nevada. Thomas (1983b:429) asserts that, "Inferences explaining this assemblage diversity in behavioral terms are clearly unwarranted in the Gatecliff case. The sample size effect explains nearly everything." This empirical generalization has, in turn, been central to the investigation of the archeological correlates of Binford's "forager-collector" continuum. It has also been quickly adopted by other investigators (e.g., Elston and Juell 1987; Parry and Christenson 1987).

Thomas (1983, 1984) went on to say, however, that archeologists could still make use of this linear relationship in order to identify residential versus logistical sites based on the slope of the regression line. Furthermore, as investigators now realize, Thomas was actually monitoring the richness component of diversity. Several investigators have now argued that efforts to measure archeological diversity have generally failed, due to the "misapplication of terminology, measures, and significance of the concept of diversity..." (Bobrowsky and Ball 1989). Bobrowsky and Ball (1989:10) also point out that comparative archeological studies of richness pose additional problems, due to the fact that "discrepant typolgies cannot be compared in the analysis of richness." This means that all investigations of diversity based solely on the richness component would have to make use of an identical artifact typology.

A number of archeologists have expressed considerable concern for the statistical effects of sample size on diversity measures. Bobrowsky and Ball (1989:11) have suggested that such effects can be dealt with by archeologists if "one can compare collections containing equal numbers of individuals, or unequal samples of completely inventoried populations..." Sample size is closely correlated to richness. Furthermore, sample size is indirectly related to evenness (J'), since it is a ratio of maximum diversity (H_{max}) to observed diversity (H'); maximum diversity (H_{max}) is equal to the log of S (number of classes or species or richness). Several archeologists have also argued that the Shannon-Weaver information (diversity) index (H') is also sensitive to sample size (e.g., Bobrowsky and Ball 1989).

Recent archeological investigations in southeastern Utah have examined assemblage content variability in terms of heterogeneity that includes both a measure of class richness (i.e., number of artifact categories), as well as a measure of class proportionality or evenness (Kramer 1991; Kramer et al. 1991; Osborn, Vetter, and Hartley 1987). These studies have challenged current arguments regarding empirical and statistical generalizations about artifact assemblage diversity and sample size. We have argued that measures of assemblage heterogeniety based solely on artifact class richness are inappropriate for assessing archeological variability, given the strong statistical relationship with sample size. Our studies in southeastern Utah have made use of the Shannon-Weaver information statistic to measure artifact assemblage diversity. As a result of these studies, we have found that artifact assemblage diversity measured in terms of the Shannon-Weaver information statistic does not vary directly with sample size.

The present analysis is designed to investigate intra-assemblage variability with respect to variable spatial scales within the boundaries of two large, extensive, lithic scatters that were investigated on the Island-in-the-Sky. These two large artifact scatters include the Alcove Spring location (42SA8512) and the Murphy Point location (42SA8500). Variation in both assemblage content and spatial distribution will then be interpreted in relation to the diversity and spatial structure of past human activities. Ultimately, our explanations of variations in pattern diversity both within and between sites must be derived from current anthropological and archeological theory regarding hunter-gatherer patterns of land use. The following discussion of hunter-gatherer land use is designed to link general ideas regarding prehistoric adaptations in arid lands to patterns of intersite and intrasite variability.

HUNTER-GATHERER LAND USE: INTERSITE PERSPECTIVE

Aboriginal land use strategies have been discussed in a previous chapter that deals with summer and winter home range sizes and related food-getting activities. Some of this material is reiterated here in order to construct a link between regional land use strategies and artifact assemblage variability. Adaptive strategies for contemporary hunter-gatherers have been envisioned by Binford (1980, 1982, 1983) as a graded series of increasing organizational complexity from foragers to collectors. As Binford (1980:12) has pointed out, this organizational scheme is not meant to represent "two polar types" or mutually exclusive classification of extant hunter-gatherers. Instead, foragers and collectors represent two contrastive forms of adaptive responses to exploitative problems posed by the distribution, accessibility, and quality of essential resources.

Binford (1987:451) states,

> ... it should be pointed out that I have proposed two contrastive forms of organization characteristic of hunter-gatherer subsistence-labor organization, collector and forager strategies (Binford 1980). In very general terms, collector strategies operate to move resources to the consumers while forager strategies operate to move consumers to the resources. It is recognized that both strategies may appear in the organization of a single society, perhaps differentiated seasonally or with respect to other contingencies. It is also recognized that both strategies may appear to be operating simultaneously at different levels of organized behavior within the organization of a single society. In other words, while individuals are hunting they may act as collectors, although the pattern of residential movement throughout the year may exhibit characteristics of the forager strategy in that consumers are being repositioned relative to resources in the habitat.

Binford's theoretical framework for hunter-gatherers has been discussed at length by a number of investigators (Chatters 1987; Ebert 1986; Hitchcock 1982; Kelly 1980, 1983, 1985; Schalk 1978; Thomas 1983a; Torrence 1983). The reader is referred to these materials for detailed treatment of the forager-to-collector arguments.

In essence, foragers and collectors represent fine-grained (generalist) and coarse-grained (specialist) adaptive strategies described by evolutionary ecologists concerned with feeding behavior. Foragers exploit

critical resources in roughly the same proportions that they are found within their home range(s); they are generalists (Pianka 1983). Both consumers and producers within foraging groups are co-resident throughout most of the year. Individual and group demands for food, fuel, and water are generally met on a day-to-day basis. In these situations, residential moves and/or adjustments in group size and composition serve as responses to local resource depression. Efforts to gain either time or space utility from critical resources through storage or caching are quite limited.

Collectors, on the other hand, exploit essential resources in a coarse-grained or specialized manner (Pianka 1983). Resources are exploited disproportionately, relative to their occurrence in the environment. Producers transport essential resources such as food, fuel, water, and raw materials to consumers at residential locations. Collectors are characterized by the implementation of resource storage strategies. Considerable effort is expended by collectors to obtain large quantities of essential resources within a brief period of time for later use. Frequently, stored resources such as food exhibit high bulk and consequently inhibit residential mobility. The need to store essential resources among hunter-gatherers has been shown to increase as the length of the growing season decreases. Resource incongruity also increases as an inverse function of the length of the growing season.

Logistical mobility tends to replace residential mobility as a means to solve problems stemming from local resource depression, the need for raw materials, and resource incongruity. Binford (1980:344) states, "Logistical strategies are labor accommodations to incongruent distributions of critical resources or conditions which otherwise restrict mobility." Collectors must make use of logistical travel to accomplish multiple tasks including resource acquisition and monitoring (Kelly 1983).

Geographical patterns of archeological site distribution can provide correlative evidence for such past strategies of aboriginal land use. The position of forager residential sites on the landscape is expected to correlate closely with the location of high bulk critical resources such as plant and animal foods, fuel, and/or water. Constraints imposed by the quality, quantity, and/or accessibility of such critical resources can be circumvented via residential moves. The probability of site re-use is low. These residential sites for foragers would exhibit interassemblage variability primarily as a function of seasonal variations in resource availability. Intersite and/or interassemblage variability for foraging groups would be marked, given seasonal variation in critical resource availability. Artifactual assemblages would exhibit greater redundancy if seasonality were slight or if they represented similar seasons of use or occupation. There should be few, if any, specialized activity sites present in forager land use systems.

As Binford has pointed out, logistically-organized hunter-gatherers produce a more complex archeological "landscape." Residential sites tend to be highly visible archeologically given the dependence on bulk storage, attendant storage facilities, domestic structures, midden accumulations, and so forth. Like foragers, collectors also generate locations or places at which resources are procured and/or processed. In addition, storage-dependent hunter-gatherers also produce field camps for extra-residential site occupation, stations for resource monitoring, and caches for storing tools and food.

ARTIFACT ASSEMBLAGES, LAND USE STRATEGIES, AND SITE HISTORY

Archeological assemblages are"... sets of artifacts (both items and features) which are found in clustered association (normally defined stratigraphically) at or in archaeological sites" (Binford 1982:5). Such archeological assemblages are ultimately formed as the result of a number of natural and cultural processes. Our understanding of the archeological record within a given stratum, site, locality, or region is dependent on our ability to specify the degree to which these variable dynamic processes contributed to the formation of static remains.

Assemblage or content variability within specific archeological sites will vary as a function of its stability of use (Binford 1978b:483-497). Stability of site use is, in turn, a function of the mobility strategies employed by hunter-gatherers in a given setting. Topographically-fixed loci such as mountain passes, mesa tops, rapids or cataracts, fords, caves/rockshelters, lithic source areas and so forth frequently emerge as special-purpose sites within hunter-gatherer land use systems. As a result, Binford (1978b:491) states, "Special-purpose locations are more discrete in their location and more redundant in their use and contents."

In contrast, residential sites and transient camps are less likely to be reused or re-occupied since their locations are more likely to be conditioned by the variable location and abundance of critical resources such as food, fuel, and water. Residential sites are "more flexible in their location and more variable in their content" (Binford 1978:491).

Repetitive use of a given geographical location would vary in relation to a given hunter-gatherer group's differential use of residential versus logistical mobility. Foragers making use of a very large home range might not be expected to establish residential sites at the same point on the landscape year after year unless they were mapping on to point resources such as springs or waterholes (Binford 1982). Residential sites for collectors would be expected to be re-used, as greater amounts of energy and time were invested in the adoption of a food storage strategy and the construction of permanent residential and storage facilities. Repetitive use of specific locations for residential and special-purpose activities would increase as group mobility decreased and as home ranges contracted (Binford 1982). Given these generalizations regarding aboriginal land use, archeologists might then expect to observe decreased intrasite content variability or increased content redundancy—particularly for special-purpose locations.

HUNTER-GATHERER ACTIVITY PATTERNS: INTRASITE PERSPECTIVE

Binford (1983:144) states that,

> ...one of the Big Questions archaeologists are currently seeking ways to understand is how early man organized his life space—the location and the spatial relationship of activities such as sleeping,eating, food-getting, tool manufacture, etc.

Contemporary understanding of the structure and dynamics of hunter-gatherer activities at particular places on the landscape is the result of a number of ethnoarcheological studies. Some of the most significant investigations of hunter-gatherer site structure and activity patterns examine the !Kung (Brooks and Yellen 1987; Yellen 1977), the Kua and Tyua (Hitchcock 1982, 1987), the Fulani (David 1971), the Zulu (Oswald 1987), the Ngatatjara (Gould 1968; Gould and Yellen 1987), the Alyawara (Binford 1987; O'Connell 1987), the Western Apache (Longacre and Ayres 1968), the Nunamiut (Binford 1978, 1983; Graham et al. 1982), and the Navajo (Kelley 1982).

These ethnoarcheological investigations have provided us with a number of general patterns for human use of space within settlements and special-purpose locations. Several of these patterns, particularly those that deal with area requirements, will be utilized in this study to define spatial units of analysis. Such ethnoarcheological observations are cross-cultural in nature and are, in turn, linked to uniformitarian arguments concerning human body size and structure (Binford 1983:145). Cross-cultural data concerning the areal requirements for various hunter-gatherer activities will be presented here in order to develop appropriate spatial scales and grid sizes for intrasite pattern diversity analysis (Table 60).

Given this preliminary data regarding hunter-gatherer activities and their spatial requirements, three grid sizes have been chosen for an examination of intrasite pattern diversity at the Alcove Spring (42SA8512) and the Murphy Point (42SA8500) artifact scatters. The smallest grid sizes included a 2-m x 2-m grid and/or a 3-m x 3-m grid. The two-meter grid size approximates the spatial requirements for an individual conducting a range of activities in a seated position. Such activities might include "flint knapping," cobble testing, tool manufacture/maintenance, or food processing/cooking/consumption. A 10-m x 10-m grid was also used to monitor the effects of spatial scale on artifact assemblage heterogeneity. This approximates Yellen's (1977:103-104) limit of nuclear area, total (LNAT) or limit of nuclear area, scatter (LNAS) within !Kung residential camps. They equal 122 and 116 sq m, respectively. These spatial units constitute the area covered by all huts, hearths, and associated debris scatters. And, a 100-m x 100-m grid unit represented the maximum spatial scale used in this analysis. This grid size was selected as an appropriate spatial unit for "capturing"several contiguous or overlapping residential camps produced by foragers or fields camps produced by collectors.

INTERNAL ORGANIZATION OF ARTIFACT SCATTERS AND LAND USE

Patterns of past hunter-gatherer land use are causally linked to intrasite variability. Variation in aboriginal group size, the number of and distance between residential moves, and shifts between fine- and coarse-grain adaptive responses to resource structure would have contributed to variable site histories (e.g., Binford 1973, 1978a, 1980, 1982; Camilli 1983). These factors, in turn, would have conditioned the position, frequency and character of site use/reuse, and the ultimate configuration or internal structure of sites. Ultimately, then, intrasite variability can be interpreted with reference to patterns of past aboriginal land use on a regional level. Such archeological variability is observable in terms of artifact assemblage diversity and site structure, i.e., pattern diversity.

The concept of pattern diversity has been modified in the present study to monitor artifact assemblage variability with reference to a spatial dimension. It should be pointed out that this application of the pattern diversity concept from community ecology is not an example of direct borrowing from another discipline. This ecological concept is, essentially, used as an analogy. Ultimately, the interpretations of pattern diversity are based on archeological/anthropological theory and make use of a static, inanimate archeological record. The results of this study will be used to evaluate contemporary questions regarding past human behavior.

MEASUREMENT OF INFORMATION AND ARTIFACT ASSEMBLAGE DIVERSITY

The information index developed by Shannon and Weaver (1949) for information and communication theory was chosen for this purpose. The Shannon index is a measure of population heterogeneity or dual-concept diversity in which the number of observational categories (richness) and their proportional representations (evenness) are monitored simultaneously (Margalef 1958, 1963, 1968; Peet 1974; Pielou 1966a, 1966b, 1975). Shannon's index or information statistic has been utilized by ecologists to monitor simultaneously the diversity and information content of communities or collections.

Pielou (1966a:131) states,

> Diversity in this connection means the degree of uncertainty attached to the specific identity of any randomly selected individual. The greater the number of species and the more nearly equal their proportions, the greater the uncertainty and hence the diversity.

The Shannon information statistic or diversity index is as follows:

$$H' = -\Sigma\, p_i \log_2 p_i$$

(where H' = information content per individual; p_i = proportion of the *i*th category).

Information content, assemblage diversity, and uncertainty are, in turn, closely linked to the concepts of entropy and the organization of physical and living systems (Brillouin 1950; Margalef 1958, 1968; Miller 1965; Patten 1959). Ecological communities, biological collections, or an assemblage of signals are said to exhibit low diversity, lack of organization, and low information content if they are composed of few components and/or a marked disproportionate representation of components. On the other hand, assemblage diversity is high, organization is great, and information content is high if components are numerous and individuals are equally apportioned among the components.

A measure of evenness in the distribution of items/observations among these components of an assemblage is provided by the following formula:

$$J' = H'/\log_2 S \quad \text{or} \quad H'/H_{max}$$

(where J' = evenness; S = number of categories or richness; H' = Shannon information index; and H_{max} = maximum information value).

Evenness (J') is used by ecologists, for example, to express the degree to which individuals are equally distributed across a given number (S) of species. Evenness and richness increase as the Shannon index (information statistic) approximates H_{max}. Redundancy within an assemblage, collection, or set of observations increases as H' diverges from H_{max}. An index of redun-

dancy exhibited by a set of observational categories is provided by the following expression:

$$R = 1 - H'/H_{max} \quad \text{or} \quad 1 - H'/\log_2 S$$

The Shannon index and the redundancy index described above can be used to express the diversity and redundancy of archeological assemblages. Like the cumulative frequency method used by Bordes, Shannon's information index allows us to monitor variability exhibited by the entire artifact assemblage. In addition, however, the Shannon index can also be used in a broader conceptual framework to measure evenness, redundancy, maximum/minimum information, and organizational complexity.

Ecologists have proposed that different diversity measures should be used, depending on the nature of the collections or assemblages under study. Pielou (1966a) suggests that Brillouin's diversity statistic should be utilized if the collection/assemblage is finite and both the total number of individuals and species are known. Pielou (1966a) also suggests that the Brillouin index reflects sample size whereas the Shannon index does not. The Shannon index should be used for calculating the information content or diversity when assemblages are infinite, total number of individuals and species are unknown, and samples are the focus of investigation. Peet (1974:293) argues that Brillouin's index " ... does not provide an acceptable index of heterogeneity." The Shannon index and associated measure of H_{max} are utilized here in order to avoid the complexities inherent in the use of Brillouin's index and H_{max} calculation.

Measures of artifact assemblage diversity (H'), maximum diversity (H_{max}), evenness (J'), and redundancy (R) will be calculated for select 2 x 2, 3 x 3, 10 x 10, and 100 x 100 meter grid units. These measures of artifact assemblage variability from spatial units of different scales will then be compared to assess the degree of pattern diversity exhibited within the Alcove Spring (42SA8512) and Murphy Point (42SA8500) lithic scatters. These intrasite comparisons at varying spatial scales will then be used to interpret the assemblage content and spatial diversity with reference to hunter-gatherer land use in the region.

PATTERN DIVERSITY: ASSEMBLAGE DIVERSITY AND SPATIAL DISTRIBUTION

Pielou (1966b) discusses the utility of using both concepts of species diversity and pattern diversity for investigating successional change in ecological communities. These changes in community organization are reflected by shifts in species numbers, proportions, and spatial pattern(s). Species diversity is expressed in terms of the information statistic adopted by Margalef (1958, 1968) from communication theory (Shannon and Weaver 1949). Maximum diversity, in this case, is achieved within a particular ecological community when all species are represented by equal numbers of individuals.

The ecological concept of pattern diversity was developed as a measure of the spatial distribution of various species within a given community. A measure of pattern diversity expresses the degree to which a sample of neighboring individuals reflects the species diversity of the entire community, population, or collection. If the individuals of the different species are distributed randomly and are not segregated, then "... any group of n neighboring individuals is equivalent to a simple random sample of size n drawn from the whole population" (Pielou 1966b:375). Pattern diversity is low if species diversity within a sub-area of the community is lower than that for the entire community. Pielou (1966b:376) states, in this regard, "... in a community of low pattern-diversity a large proportion of the total area must be examined before every species belonging to the community is encountered." Pattern diversity is high if all species are represented in the smaller sample (Pielou 1966b:376).

Pattern diversity (D) is expressed as a ratio of the mean species diversity for a large sample of groups, H(n), divided by the expected value of H for a simple random sample, E[H(n)].

$$D = H(n)/E[H(n)]$$

For randomly distributed or unsegregated communities, the value of D equals 1. If the species within the community are clumped or segregated, pattern diversity is significantly less than 1 (Pielou 1966b:376).

In the present study, pattern diversity of artifact assemblages was examined in a somewhat different manner. The information statistic was utilized to monitor assemblage diversity. However, the Shannon-Weaver information index for each grid unit was standardized by dividing H' values by H_{max}. This standardized diversity measure is referred to as relative information (Rel. H'_n) (Krippendorff 1986:18). This measure of relative information is equivalent to J' (evenness) used by ecologists. In the present study, values of J' were automatically calculated for each set of artifacts observed in a particular grid unit. Furthermore, a redundancy measure (R) was also calculated; its value increases as relative H_n or J' (evenness) approaches 1.0. Since it incorporates a measure of relative information (H_n), it is a standardized index in relation to the number of artifact categories represented in a given grid unit or collection. We must also emphasize that values of J' or relative diversity are invariant with sample size (R.W. Thomas 1981:13). Changes in artifact assemblage variability relative to changes in spatial scale will be assessed here in terms of the redundancy measure (R).

ANALYSIS

The purpose of this analysis is to assess the degree of spatial patterning of artifact assemblage heterogenity within two extensive artifact scatters in the Island-in-the-Sky District of Canyonlands National Park, Utah. As mentioned, this investigation of intrasite artifact distribution is designed to monitor changes in assemblage diversity associated with shifts in spatial scale.

Alcove Spring Location (42SA8512)

This location (42SA8512) consisted of an extensive artifact scatter and subsurface deposits. The lithic artifact assemblage contained 1,803 items from the surface and 210 items that were recovered from the excavations. Biface thinning flakes and pressure flakes dominated the identifiable debitage recovered in the excavations. One 100-m x 100-m grid unit was superimposed on this artifact concentration; it contained 1,221 items that represented 68 percent of the total surface assemblage. In addition, the surface scatter at Alcove Spring was subdivided into 144 grid units that measured 10 meters by 10 meters. Seven grid units contained artifacts; these units contained from 4 to 522 items, or a total of 996 lithic items. This location was then gridded into 1,156 individual 3-m x 3-m meter units. Only 12 of these units contained artifacts (826 total items).

Artifact class numbers and artifact frequencies per class were then utilized within the DIVERS computer program to calculate a series of diversity-related measures including the Shannon information index (H'), maximum diversity (H_{max}), evenness (J'), and redundancy.

Diversity (H') for the 100-m x 100-m grid equals 0.172; H_{max} equals 2.807; evenness equals 0.061; and redundancy equals 0.939 (Figure 112).

Diversity (H') values for the 10-m x 10-m grids range from 0.094 to 0.811. Maximum diversity (H_{max}) ranges from 1.000 to 2.322. Evenness (J') ranges from 0.060 to 0.811 (mean = 0.3376); and redundancy ranges from 0.189 to 0.940 (mean = 0.6624) (Table 61). This information is represented graphically in Figures 113 and 114.

Diversity (H') values for the 3-m x 3-m grids range from 0.116 to 1.000. Maximum information ranges from 1.000 to 2.000. Evenness ranges from 0.044 to 1.000 (mean = 0.4079), and redundancy ranges from 0.000 to 0.956 (mean = 0.5921) (Table 61). The variation of diversity and maximum diversity are presented in Figure 115 for 12 grid units that produced artifactual material. Observed diversity values (H') rarely approximate the maximum possible diversity (H_{max}). The relatively redundant nature of the artifact samples in these 12 grid units is illustrated in Figure 116.

Diversity (H') is not directly related to sample size; in fact, a linear regression of artifacts collected within the 3-m x 3-m grid units reveals that H' is inversely related to sample size ($r = -0.6582$; $R = 0.4333$; adjusted $R = 0.433$; $df = 11$; $p = 0.020$). And, redundancy is weakly, yet positively, related to sample size ($r = 0.6722$; $R = 0.4518$; adjusted $R = 0.4518$; $df = 11$; $p = 0.017$).

This lack of correlation between the diversity index (H') and sample size can be observed in two "fishnet" plots (Figures 117 and 118). Artifact assemblage diversity is observed to increase in areas of the Alcove Spring location that exhibit low artifact frequencies.

The same patterns are reflected in linear regressions for the artifacts collected within the 10-m x 10-m grid units. These regressions obviate the concerns expressed by a number of archeologists that have investigated the effect of artifact or ecofact sample size on diversity measures.

Murphy Point Location (42SA8500)

This location included a surface artifact scatter that contained 32,148 items; excavations at this location yielded an additional 100 items. One 100-m x 100-m grid unit was superimposed over this surface scatter. It contained 11,147 items that represented approximately 35 percent of the surface assemblage. A total of 144 grid units measuring 10-m x 10-m was also superimposed over this surface artifact concentration. Only 22 of these 10-m x 10-m units contained artifacts (4,804 items). A portion of this location was also gridded into 1,156 grid units that measured 3 m x 3 m. Twenty-six of these units contained artifacts (1,452 items).

The diversity (H') value for the 100-m x 100-m unit equals 0.031; H_{max} equals 2.807; evenness equals 0.011; and redundancy equals 0.988 (Figure 119).

The diversity (H') values for the 10-m x 10-m grid units range from 0.015 to 0.544. The maximum diversity (Hmax) values range from 1.000 to 1.585. Evenness (J') ranges from 0.015 to 0.544 (mean = 0.1127) (Table 62). In addition, redundancy ranges from 0.456 to 0.985 (mean = 0.8873). The ranges for these diversity-related values are illustrated in Figures 120 and 121.

The diversity (H') values for the 3-m x 3-m units range from 0.034 to 0.71; maximum diversity (H_{max}) equals 1.000 (Figure 122). Evenness (J') values range from 0.034 to 0.918 (mean = 0.3001); redundancy ranges from 0.029 to 0.966 (mean = 0.6998) (Figure 123).

A portion of this artifact scatter was also gridded into 2-m x 2-m units. A total of 1,849 units were produced; only 24 contained artifacts (621 total items). The diversity (H') values range from 0.065 to 1.000; maximum diversity equals 1.000 (Figure 124). Evenness (J') ranges from 0.065 to 1.000 (mean = 0.4609); and, redundancy ranges from 0.082 to 0.935 (mean = 0.5390) (Figure 125).

Again, regression analyses demonstrate that evenness and redundancy measures, as well as diversity, are not directly related to sample size. These regression analyses are illustrated in Figures 126-131.

SUMMARY AND CONCLUSIONS

Both Alcove Spring (42SA8512) and Murphy Point (42SA8500) are extensive artifact scatters on the Island-in-the-Sky. Murphy Point (42SA8500) is a lithic scatter that encompasses almost 140 hectares along the summit of a hogback ridge. As mentioned, this scatter produced 32,148 lithic items; however, only 160 items (0.50 percent) were classified as flaked stone tools. The remaining 99.5 percent of this lithic assemblage was classified as debitage. Artifact class richness remained quite low regardless of what size grid unit was used; it never exceeds a value of 3, even within the 100-m x 100-m grid unit. Mean redundancy values increased rather sharply as grid size was increased (Table 63). This marked increase in the redundancy of artifact samples indicates that the debitage category (i.e., flakes, incomplete flakes, and shatter) constitutes the greatest proportion of the assemblage.

The excavated debitage from the Island-in-the-Sky is dominated by biface thinning flakes, pressure flakes, and interior flakes that do not exhibit cortex. Given these observations, we suggest that the very redundant character of flaked stone artifact assemblages at Alcove Spring (42SA8512) and at Murphy Point (42SA8500) resulted from biface thinning and resharpening. Archeological evidence from the White Crack location (42SA17597) indicates that bifacial cores were produced near the lithic source area(s) (Osborn et al. 1993). These bifacial cores were then transported to locations at a higher elevation on the Island-in-the-Sky. Reduction at these sites may have either been related to tool maintenance and resharpening or to flake production. These thin, sharp flakes were then perhaps used to produce implements and facilities made from organic materials including wood, antler, bone, bark, vegetal fiber, and/or animal hides.

The redundancy indices for the Alcove Spring (42SA8512) and Murphy Point (42SA8500) locations are comparable within each grid size category to those observed at the Halls Crossing location (42SA14829) in Glen Canyon (Table 63). The redundancy index ranges

from 0.5390 to 0.6998 for these three artifact scatters within the 2-m x 2-m and 3-m x 3-m grid units. It varies from 0.6624 to 0.8873 for the 10-m x 10-m units and from 0.9390 to 0.9880 for the 100-m x 100-m units. Redundancy values for the large mapping blocks at the Neck site (42SA8502) were calculated for the East Block (244 m x 610 m), the West Block (335 m x 701 m), and both East and West blocks; these redundancy indices equal 0.931, 0.969, and 0.965, respectively (Table 63).

Artifact assemblage diversity decreases markedly, and redundancy increases accordingly, as we shift the spatial scale of our analysis within the extensive lithic scatters on the Island-in-the-Sky. The nature of this change in assemblage redundancy values is illustrated in Figure 132. The present discussion focuses primarily on variation in artifact assemblage evenness (J') and redundancy since these measures are standardized and are not sensitive to sample size effects. In general, the artifact assemblages in this case exhibit a pronounced increase in redundancy when the spatial scale is increased from four or nine square meters to 100 square meters. This decrease in diversity and corresponding increase in redundancy may indicate that the highest levels of artifact diversity reflect individual work space requirements. In absolute terms, artifact class richness, however, never exceeds two tool classes at Murphy Point (42SA8500) for the 2-m x 2-m or 3-m x 3-m grid units or four tool classes for the 3-m x 3-m grid units at Alcove Spring (42SA8512). Maximum artifact class richness for these two locations within the 100 x 100 meter grid units equals seven tool classes.

This study reveals that the extensive lithic scatters investigated on the Island-in-the-Sky exhibit low artifact class richness, low evenness, and high redundancy. Flaked bifaces and unifaces represent a very small proportion of the total flaked stone assemblage. Arbitrary grids that were superimposed over these artifacts scatters for this analysis were expanded from four or nine square meters to more than 235,000 square meters; yet the artifact class richness component only increased from 2 classes to a maximum of 10 classes at the Neck site (42SA8502). In other words, the spatial framework was expanded more than 59,000 times, but artifact class richness exhibited only a fivefold increase.

O'Connell (1987) emphasized that archeologists must begin to examine very large areas in order to delineate patterns in hunter-gatherer site structure. He (1987:104) states,

> Archaeological analyses of site structure at !Kung, Nunamiut, and Alyawara residential bases would necessarily entail assessment of variation within and between household and adjacent special activity areas.... Individual Alyawara household areas often cover more than 1,000 m^2, counting the refuse disposal zone. Clearing several might mean opening 5,000-10,000 m^2 or more, a massive undertaking by current standards. Nevertheless, some of the most interesting and potentially informative opportunities for the study of hunter-gatherer site structure may well contain patterns that approach, or even exceed the scale represented by the Alyawara ....

The spatial data recovered during our investigations on the Island-in-the-Sky can be used to study further aspects of site structure based on surface materials. The spatial frame within which these surface artifacts have been plotted measures 100 meters by 47,000 meters. The artifact displacement experiments conducted within the various microenvironments demonstrate that movement is generally limited to one-half to one square meter areas. With such control for surface scatter integrity, we believe that considerably more can be learned about prehistoric site structure and activity patterns. Such research is now feasible, given our commitment to provenience plotting of artifact scatters that were at one time ignored by archeologists.

Table 60. Cross-cultural data regarding hunter-gatherer activities and their areal requirements.

Activity	Area	Coments	Reference
Seated worker	2 x 2 = 4	Binford's idealized model	Camilli 1983
Seated worker/ forward toss bone disposal	2 x 5 = 10	Binford's idealized model	Camilli 1983
Outdoor seated worker model	2.5 x 2 = 5	Binford's idealized model	Camilli 1983
Inside woman's work area	3 x 2 = 6	Binford's idealized model	Camilli 1983
Outside stone boiling	2.5 x 2.5 = 6.2	Binford's idealized model	Camilli 1983
Chipped stone ax manufacture	2 x 2 = 4 4.5 x 4 = 18	Seated Standing	Newcomer and Sieveking 1980, in Camilli 1983
Mano manufacture	1 x 1 = 1		Nelson 1983, in Camilli 1983
Metate manufacture	1 x 2 = 2		Nelson 1983, in Camilli 1983
Kangaroo butchering	17-24 mean 20.5	Standing	Binford 1983a
Caribou butchering	30	Standing	Binford 1983a
!Kung residential sites:			Yellen 1977
absolute limit scatter	198.44		
limit most scatter	150.04		
limits nuclear area, hut circle	122.23		
limit nuclear area, scatter	116.11		

Table 61. Mean evenness (J') and redundancy values for varying grid sizes at the Alcove Spring site (42SA8512).

Grid Size in meters	Evenness (J')	Redundancy
3 x 3	0.4079	0.5921
10 x 10	0.3376	0.6624
100 x 100	0.0610	0.9390

Table 62. Mean evenness (J') and redundancy values for varying grid sizes at the Murphy Point site (42SA8500).

Grid Size in meters	Evenness (J')	Redundancy
2 x 2	0.4609	0.5390
3 x 3	0.3001	0.6998
10 x 10	0.1127	0.8873
100 x 100	0.0110	0.9880

Table 63. Comparison of mean redundancy values observed at Alcove Spring (42SA8512), Murphy Point (42SA8500), the Neck site (42SA8502), and Halls Crossing (42SA14829) lithic scatters.

Site Designation	Grid Size (meters)	Redundancy (1 - H'/Hmax)
42SA8512	3 x 3	0.5921
42SA8500	2 x 2	0.5390
42SA8500	3 x 3	0.6998
42SA14829	2 x 2	0.6085
42SA8512	10 x 10	0.6624
42SA8500	10 x 10	0.8873
42SA14829 (high density)	10 x 10	0.8760
42SA14829 (low density)	10 x 10	0.8510
42SA8512	100 x 100	0.9390
42SA8500	100 x 100	0.9880
42SA14829 (high density)	100 x 100	0.9590
42SA14829 (low density)	100 x 100	0.9690
42SA8502 (East)	244 x 610	0.9310
42SA8502 (West)	335 x 701	0.9690
42SA8502 (Combined)	———	0.9650

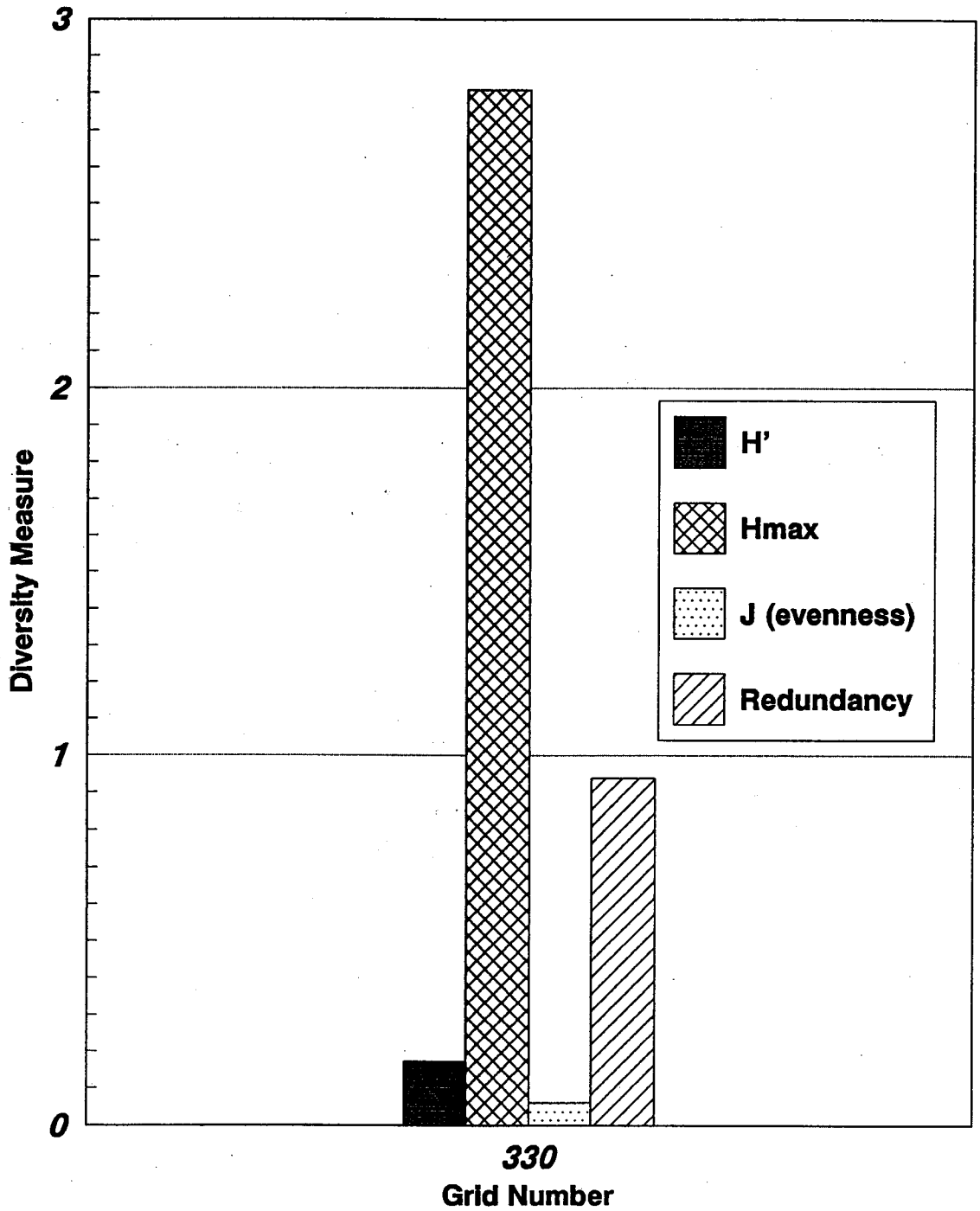


Figure 112. Artifact assemblage variability-Alcove Spring (42SA8512) 100-meter grid-diversity (H'), H_{MAX}, evenness, and redundancy.

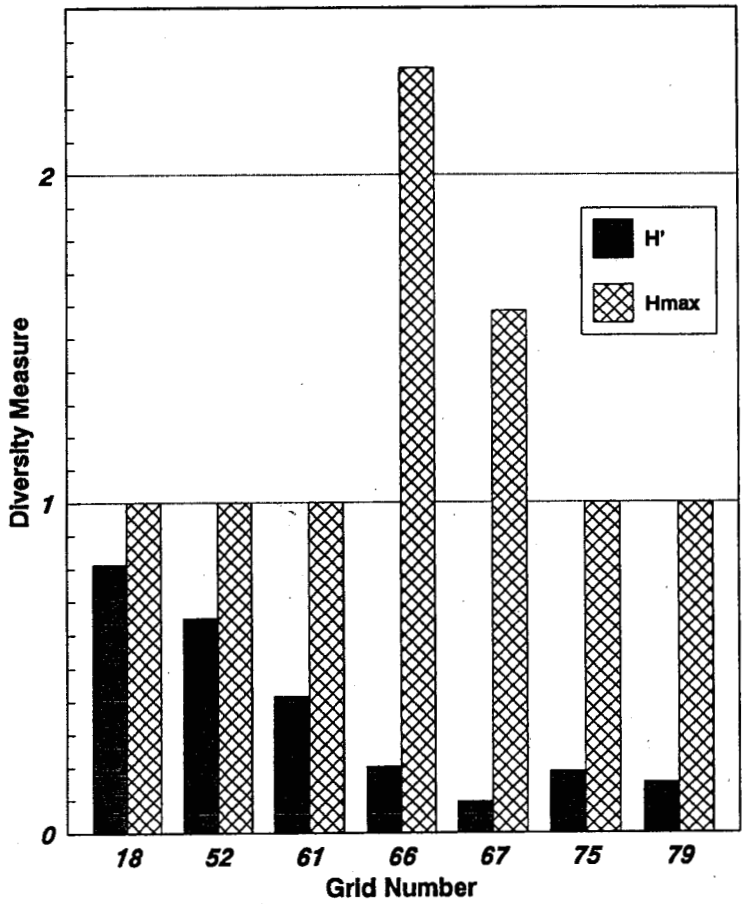


Figure 113. Artifact assemblage variability—Alcove Spring (42SA8512) 10-meter grids—diversity (H') and H_{MAX}.

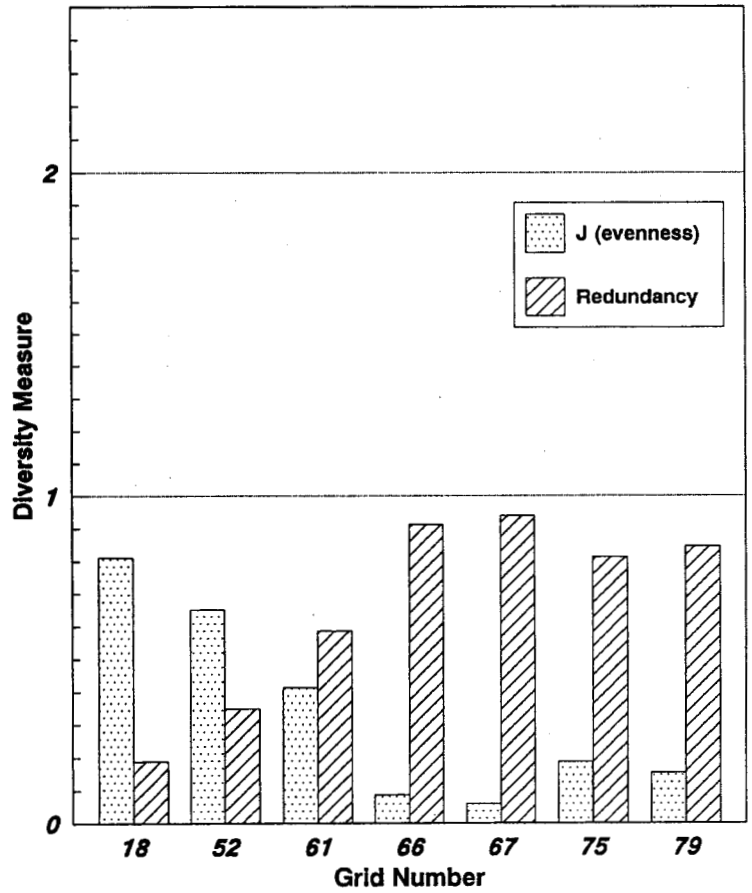


Figure 114. Artifact assemblage variability—Alcove Spring (42SA8512) 10-meter grids—evenness (J) and redundancy measures.

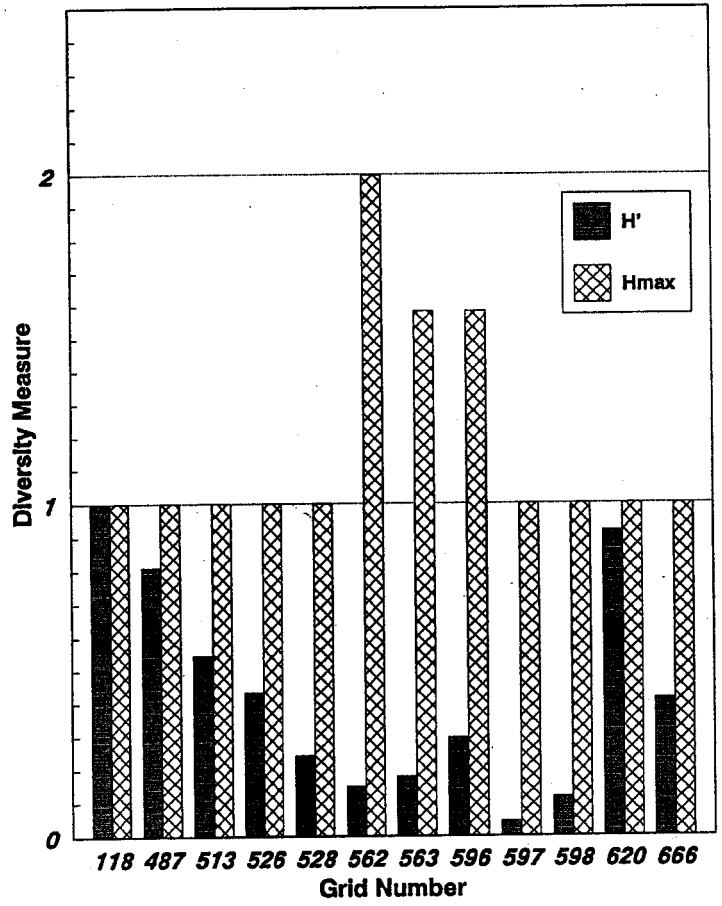


Figure 115. Artifact assemblage variability—Alcove Spring (42SA8512) 3-meter grids—diversity (H') and H_{MAX}.

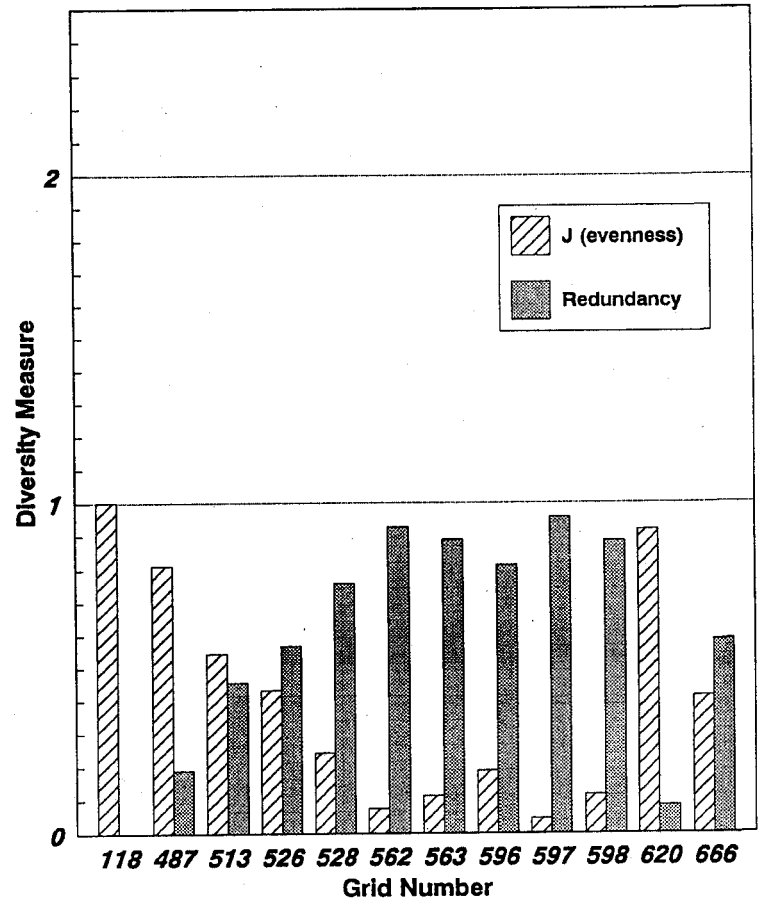


Figure 116. Artifact assemblage variability—Alcove Spring (42SA8512) 3-meter grids—evenness (J) and redundancy measures.

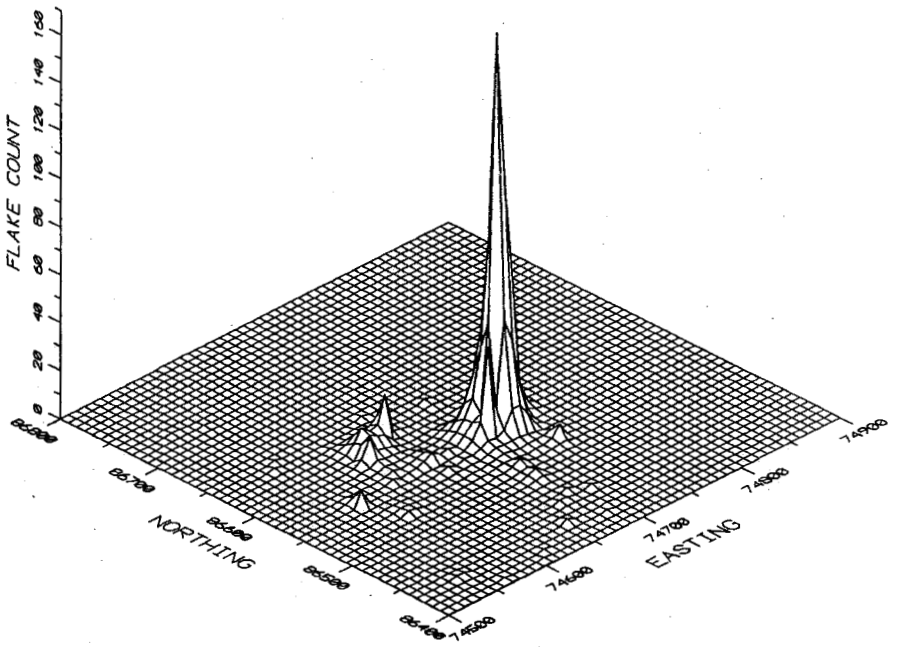


Figure 117. Fishnet plot of artifact concentration, Alcove Spring (42SA8512).

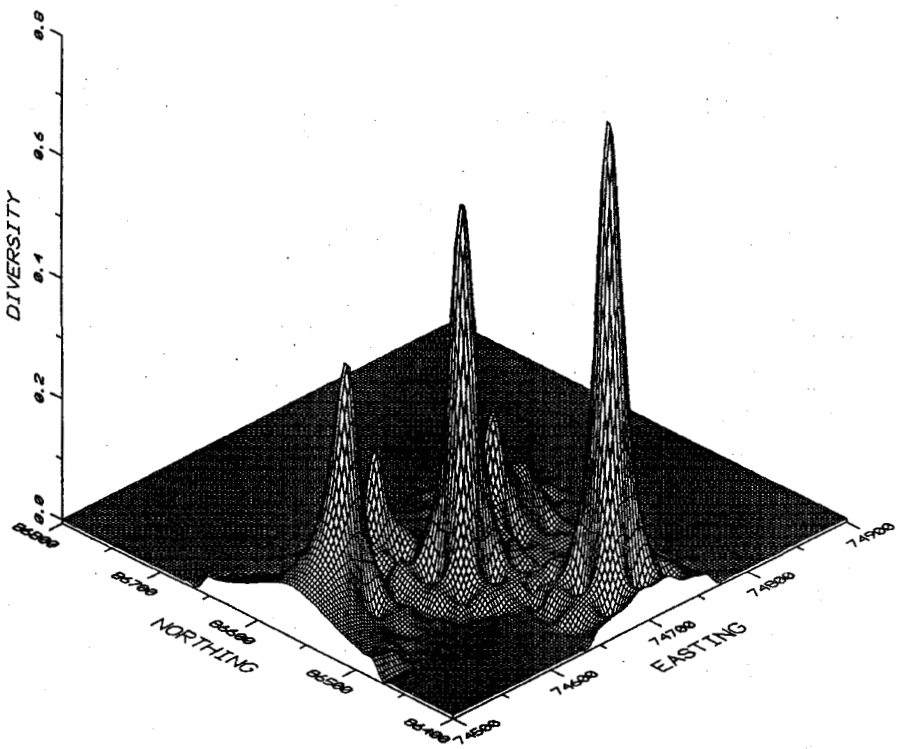


Figure 118. Fishnet plot of artifact diversity, Alcove Spring (42SA8512).

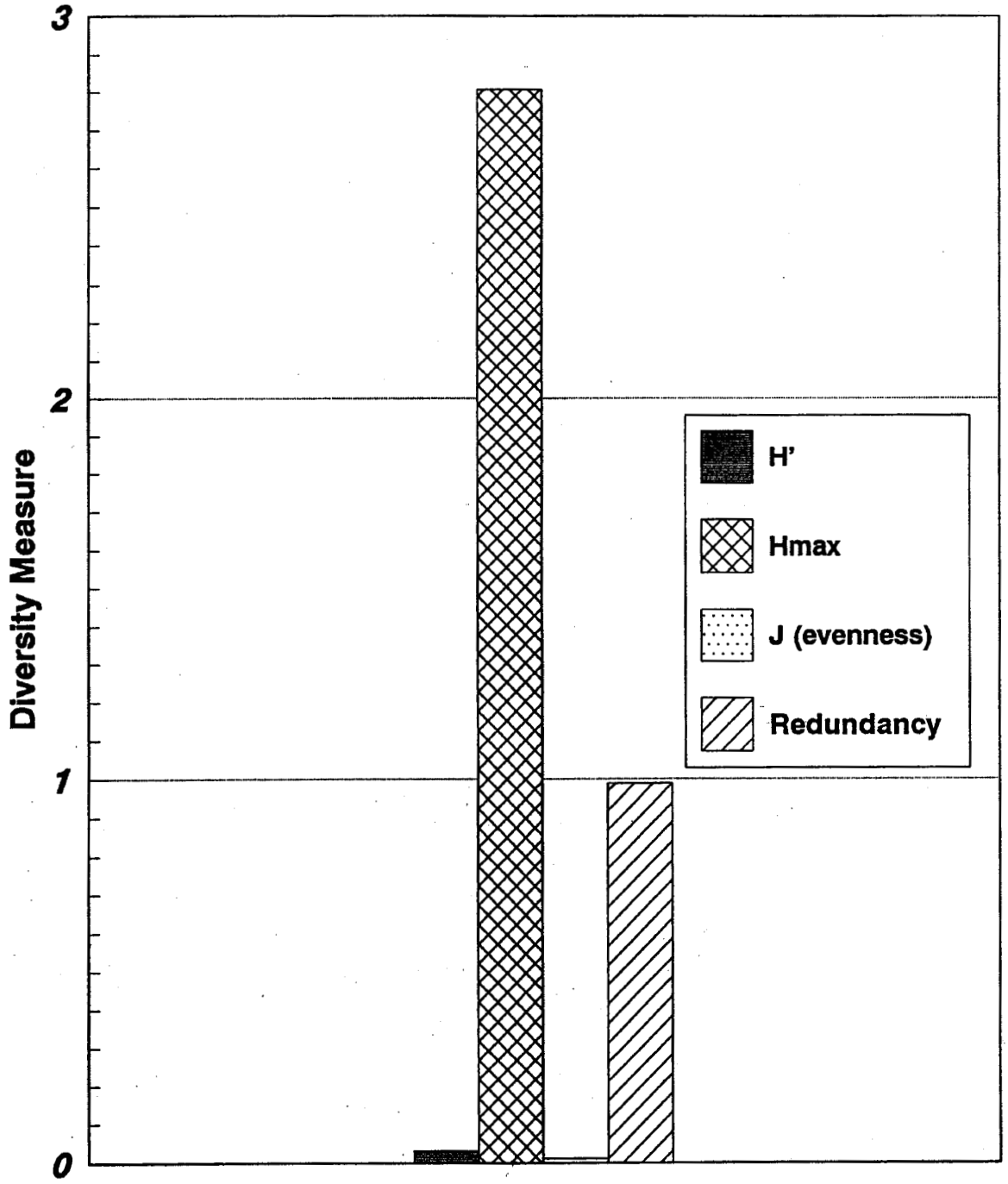


Figure 119. Artifact assemblage variability—Murphy Point (42SA8500) 100-meter grid—diversity (H'), H_{MAX}, evenness, and redundancy.

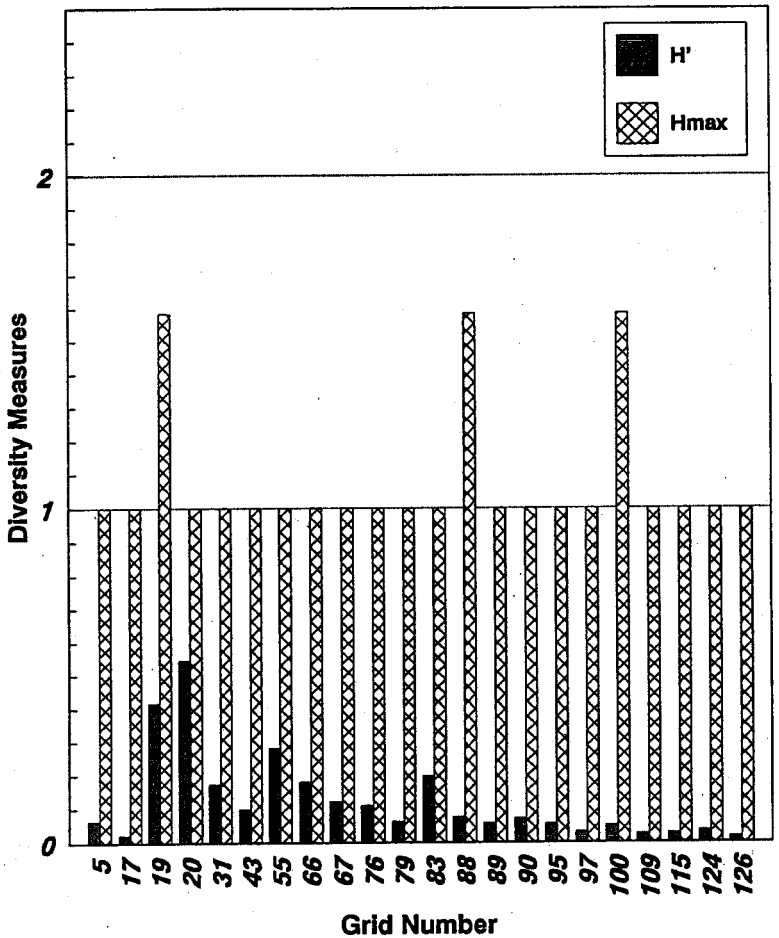


Figure 120. Artifact assemblage variability—Murphy Point (42SA8500) 10-meter grids—diversity (H') and H_{MAX}.

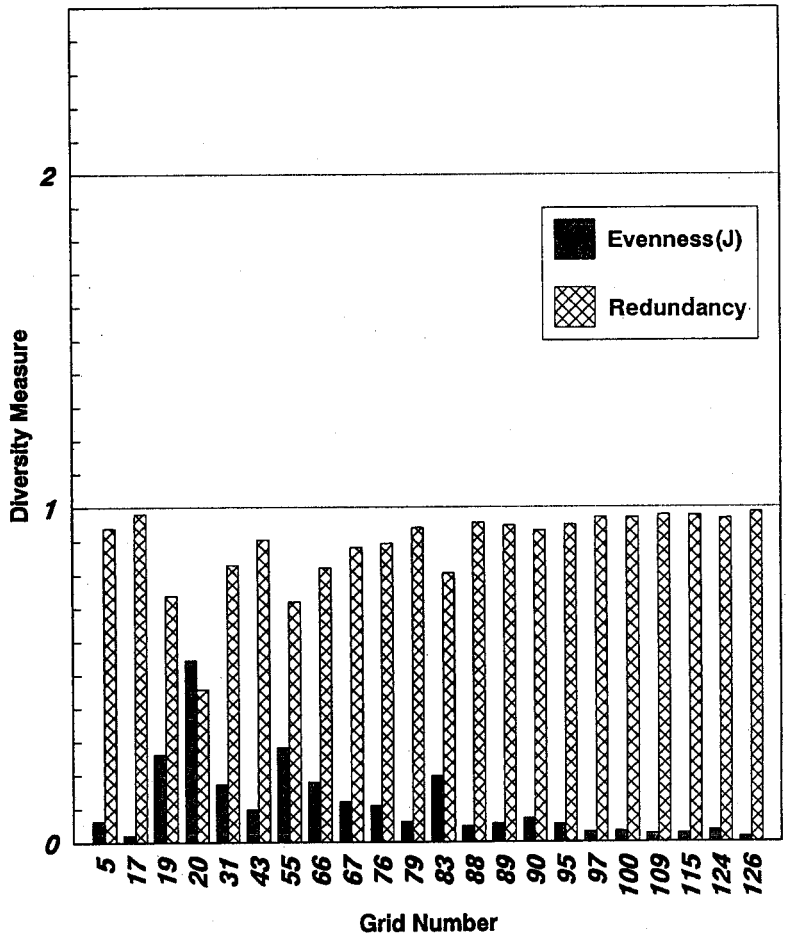


Figure 121. Artifact assemblage variability—Murphy Point (42SA8500) 10-meter grids—evenness (J) and redundancy measures.

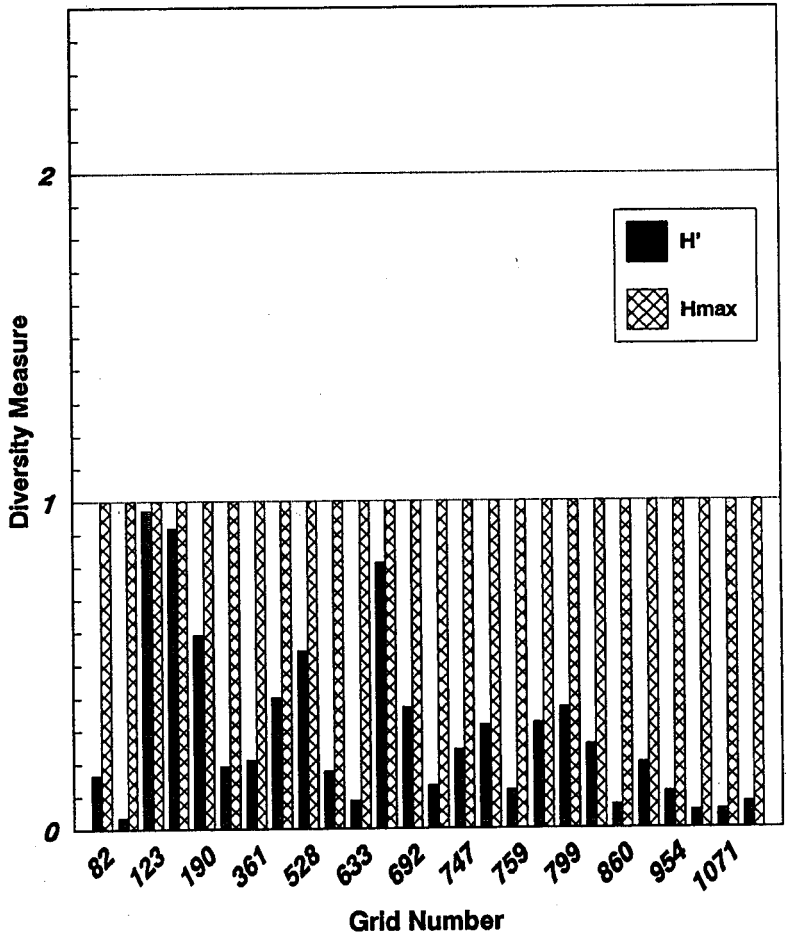


Figure 122. Artifact assemblage variability—Murphy Point (42SA8500) 3-meter grids—diversity (H') and H_{MAX}.

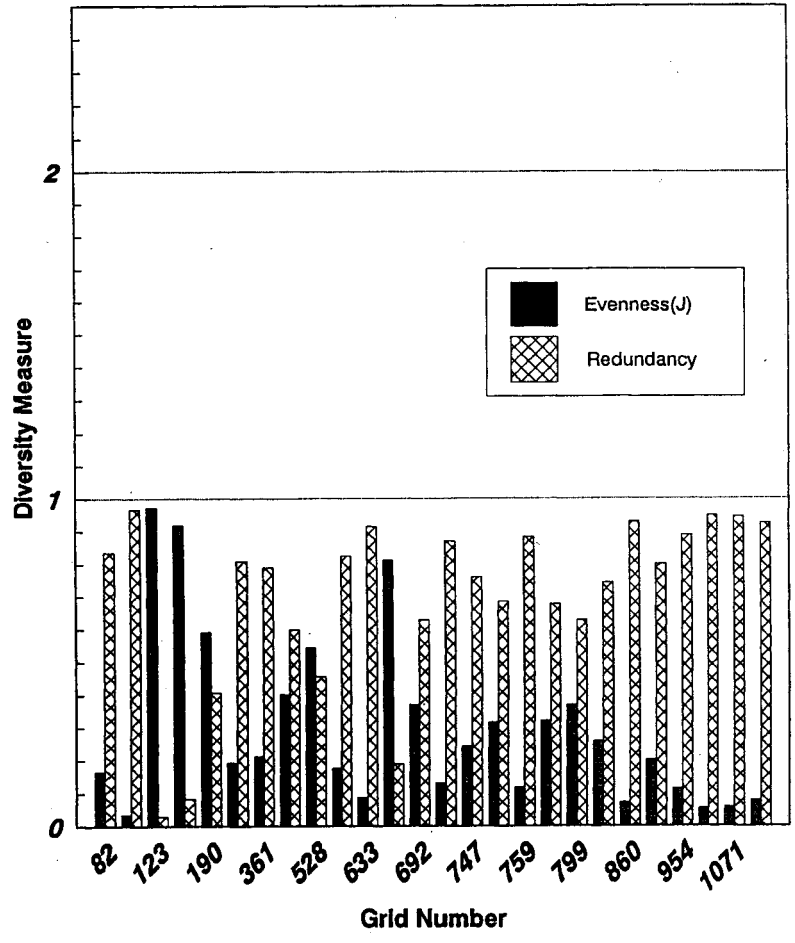


Figure 123. Artifact assemblage variability—Murphy Point (42SA8500) 3-meter grids—evenness (J) and redundancy measures.

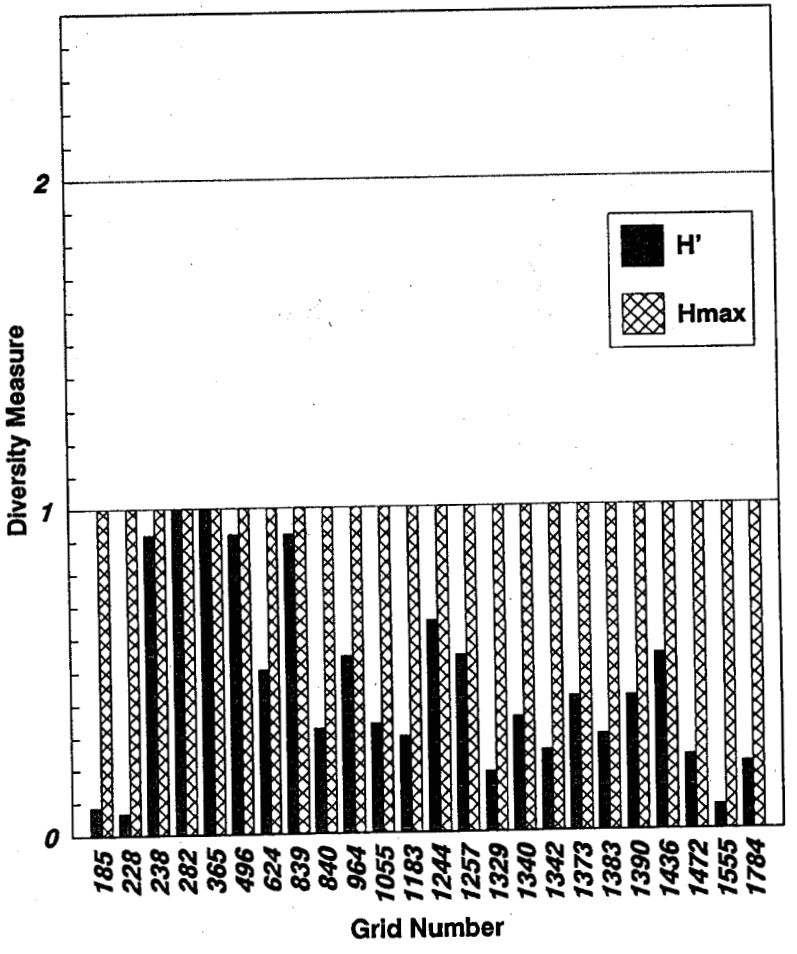


Figure 124. Artifact assemblage variability—Murphy Point (42SA8500) 2-meter grids—diversity (H') and H_{MAX}.

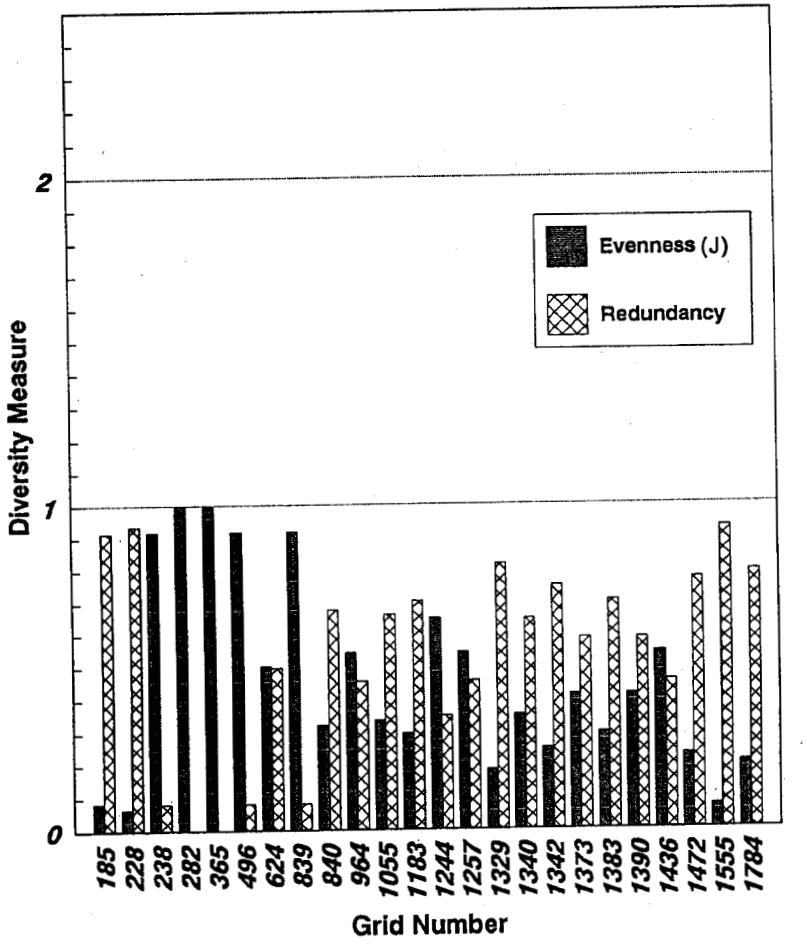


Figure 125. Artifact assemblage variability—Murphy Point (42SA8500) 2-meter grids—evenness (J) and redundancy measures.

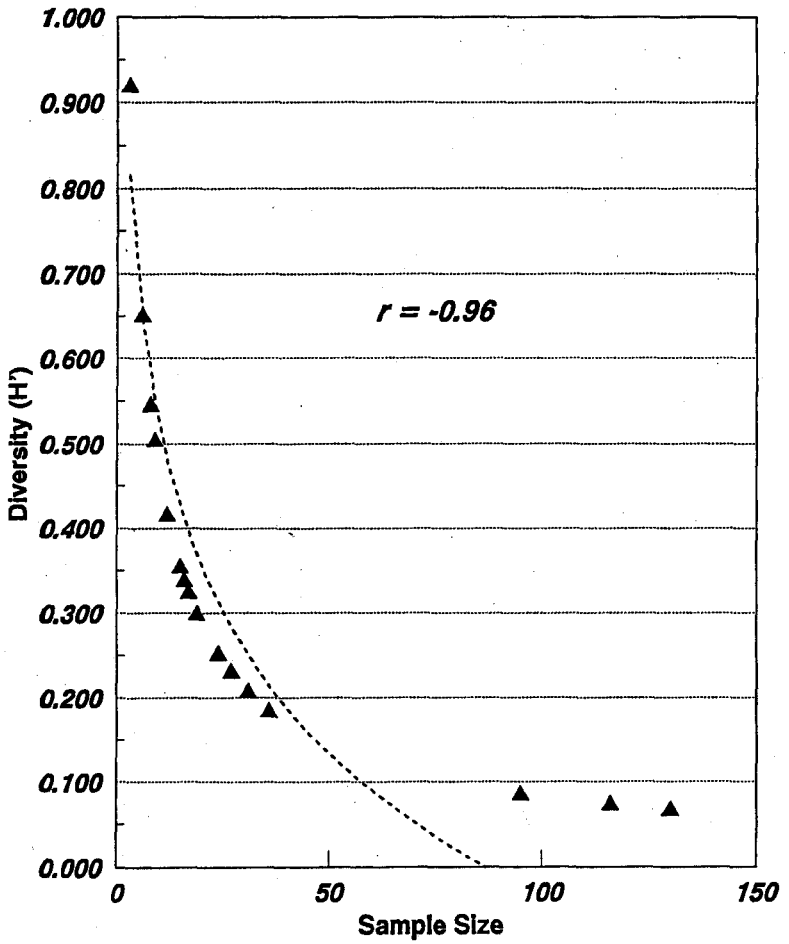


Figure 126. Artifact assemblage variability—sample size versus diversity—Murphy Point (42SA8500) 2-meter grids.

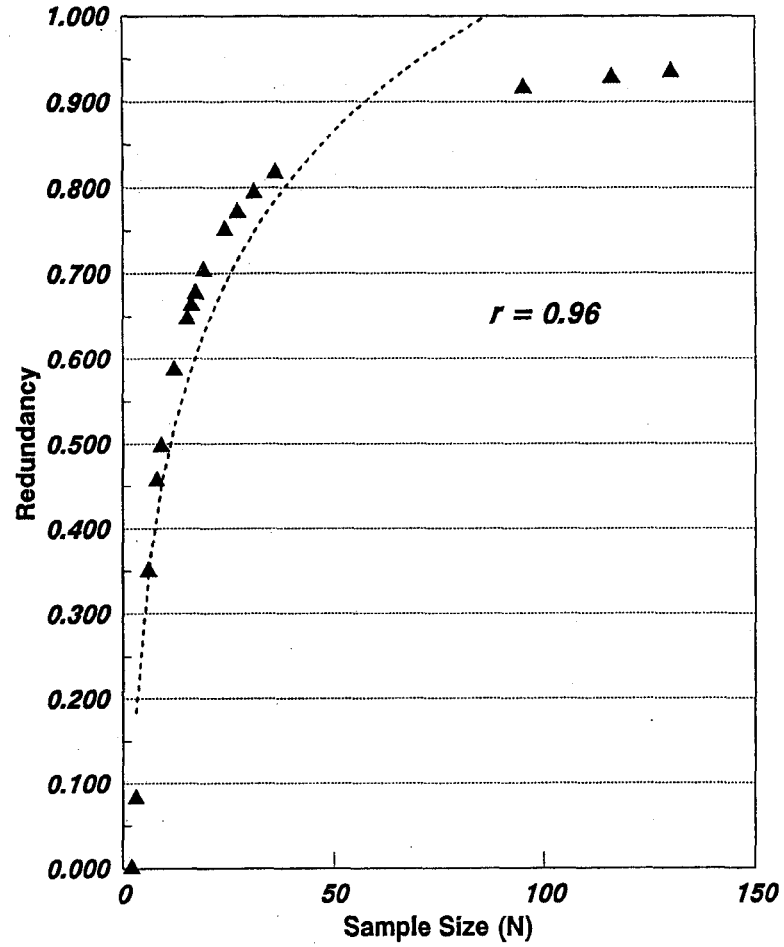


Figure 127. Artifact assemblage variability—sample size versus redundancy—Murphy Point (42SA8500) 2-meter grids.

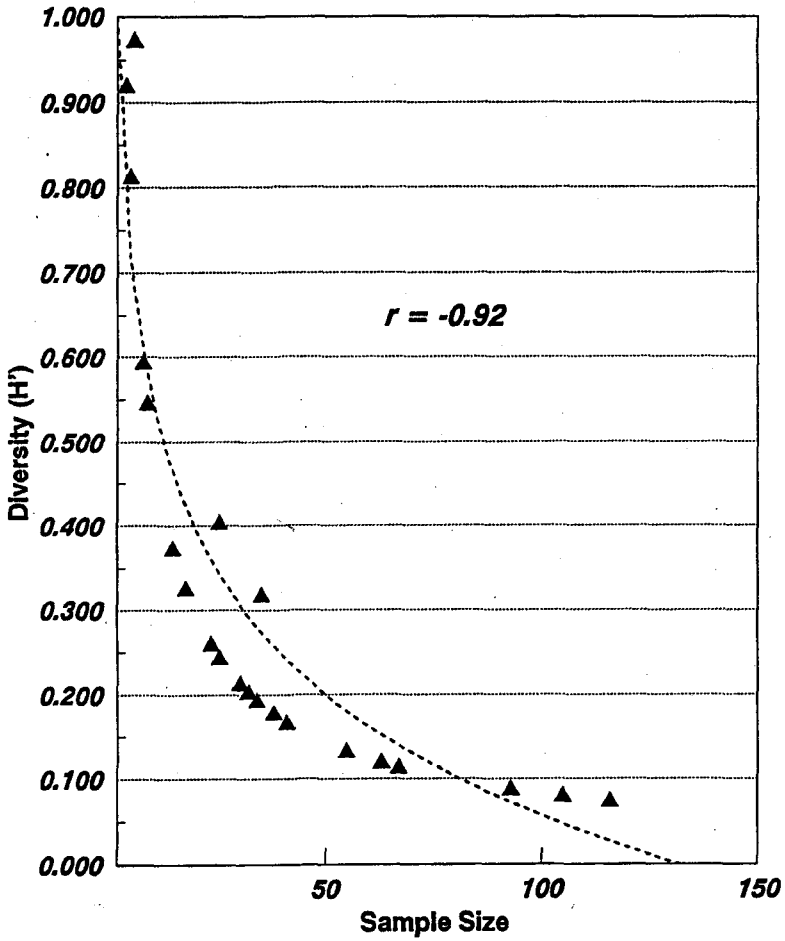


Figure 128. Artifact assemblage variability—sample size versus diversity—Murphy Point (42SA8500) 3-meter grids.

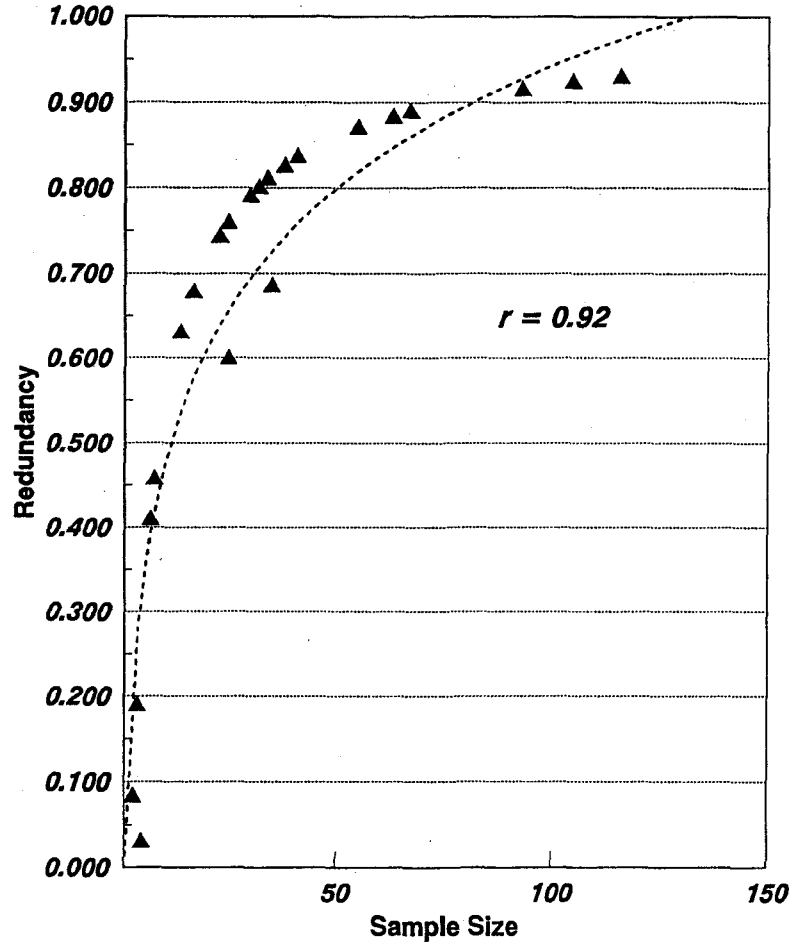


Figure 129. Artifact assemblage variability—sample size versus redundancy—Murphy Point (42SA8500) 3-meter grids.

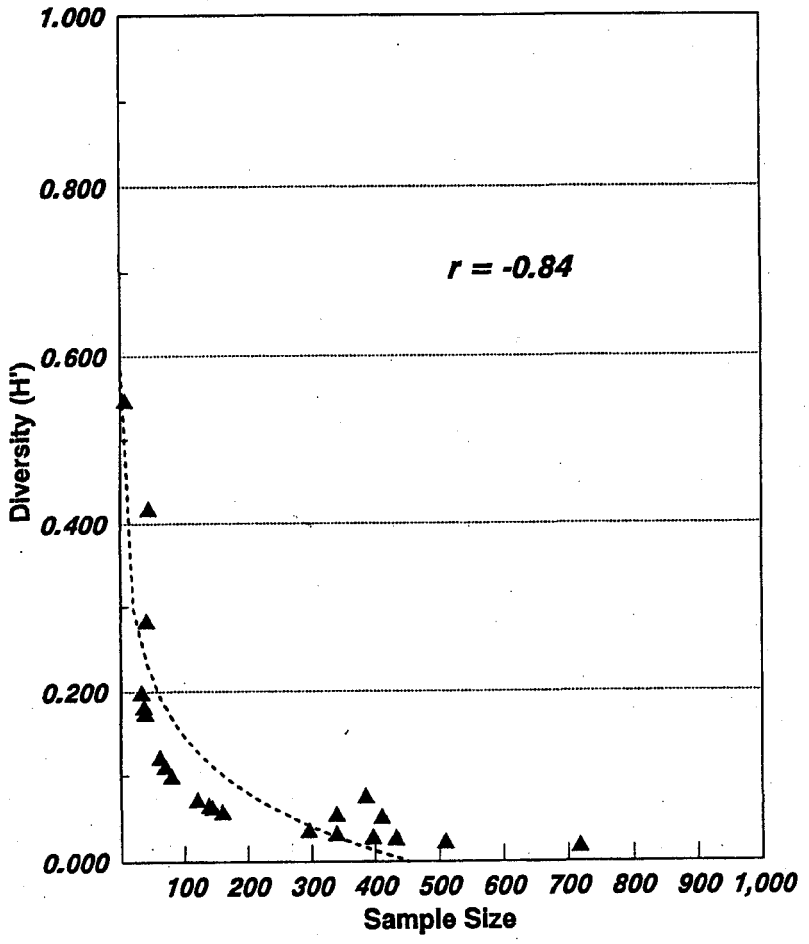


Figure 130. Artifact assemblage variability—sample size versus diversity—Murphy Point (42SA8500) 10-meter grids.

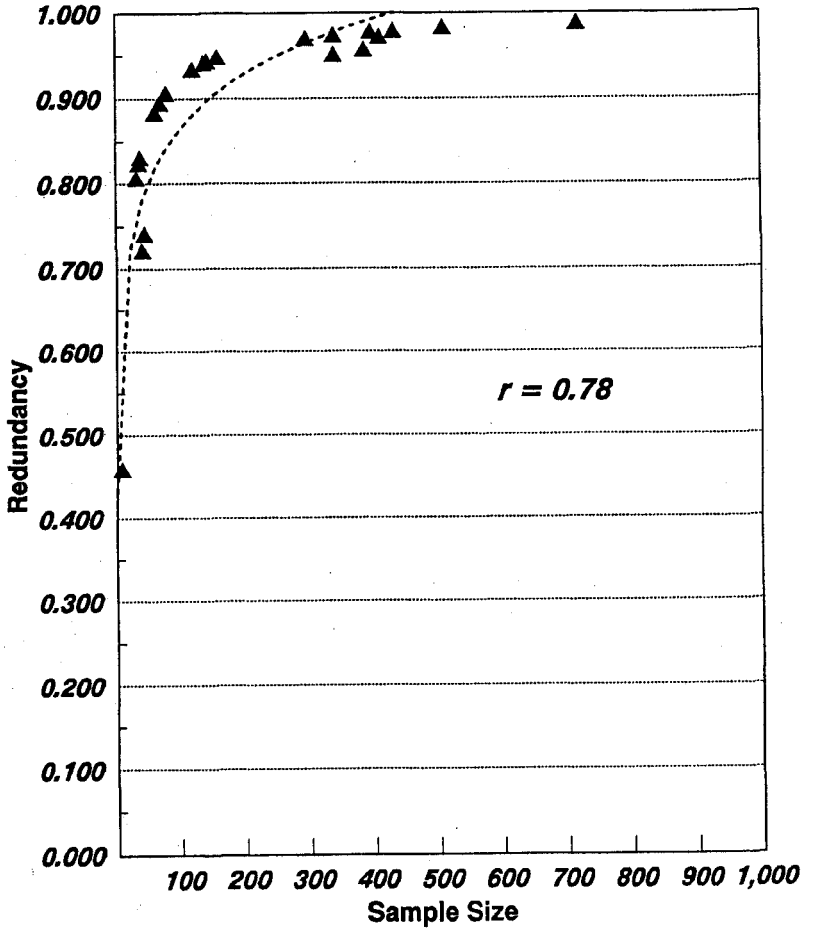


Figure 131. Artifact assemblage variability—sample size versus redundancy—Murphy Point (42SA8500) 10-meter grids.

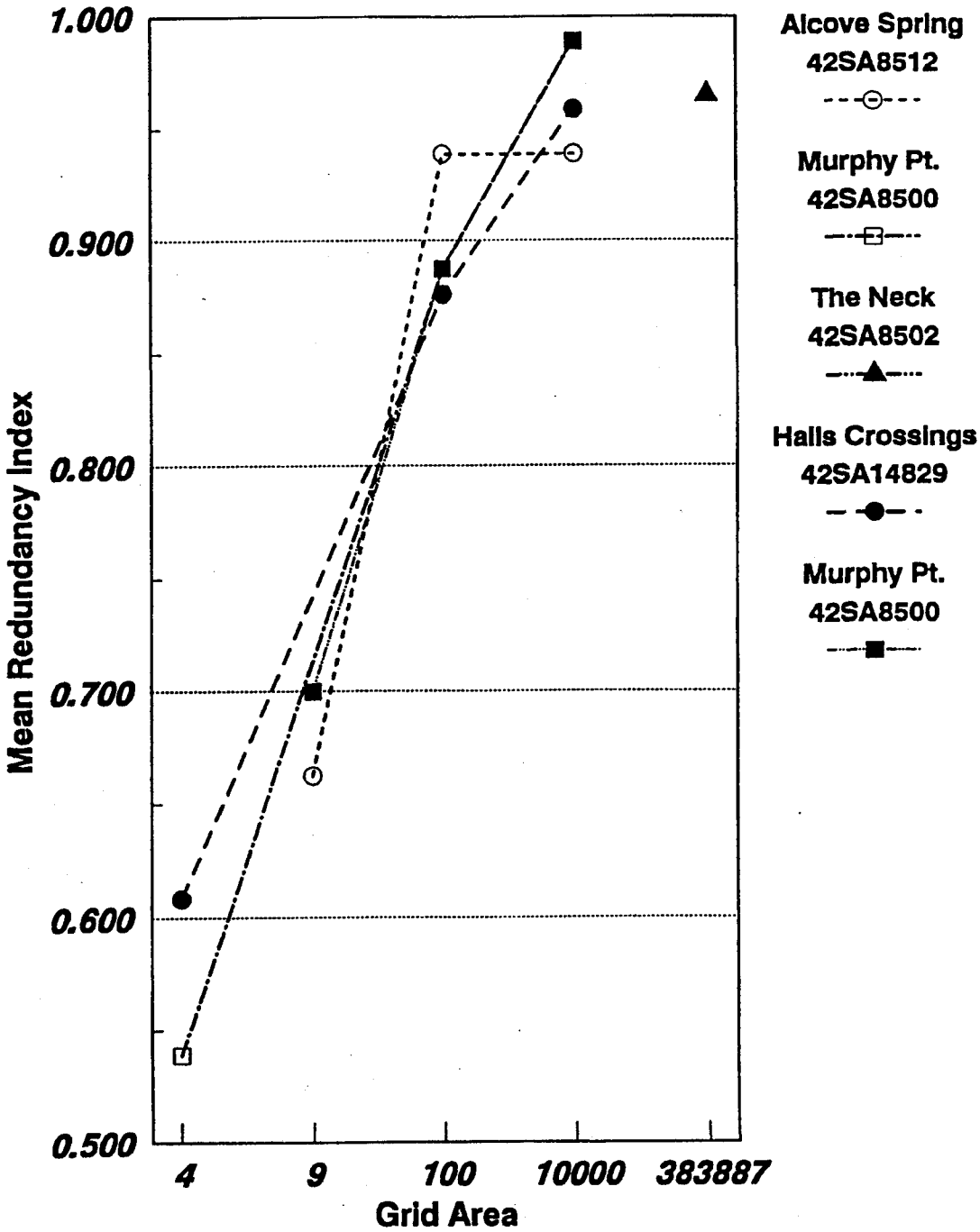


Figure 132. Artifact assemblage redundancy and grid size for Alcove Spring (42SA8512), The Neck (42SA8502), Murphy Point (42SA8500), and Halls Crossing (42SA14829).

THE FAUNAL ASSEMBLAGES

LABORATORY METHODS

The initial phase in the preparation of the faunal material from Canyonlands National Park was conducted at the Midwest Archeological Center. All unmodified bone was washed or brushed to remove soil. After cataloging, the bone was separated into identifiable and unidentifiable groups. All identifiable bone was labeled with provenience data.

Identifiable bone was defined as any specimen that could be identified to class and, through the presence of muscle attachments, fossae, and articular surfaces, to element. All fragments that were not identifiable at least to element were considered unidentifiable. The unidentifiable bone from each site was counted and set aside for taphonomic analysis.

The comparative collection at the Midwest Archeological Center was used to identify all faunal materials with the exception of bighorn sheep. A partial skeleton from the University of Nebraska State Museum's comparative collection was used to identify bighorn sheep remains. Most of the specimens were identified to genus and, whenever possible, to species. However, it was possible to identify some fragments only to the family or order level.

Each bone was examined to obtain information on the following attributes: taxon, element, side, portion, and stage of epiphyseal fusion. This information was coded and entered onto a computer diskette using dBASE III Plus. Appendix F contains code definitions for all variables used.

CALCULATION OF MNI

The most common procedure for determining the minimum number of individuals (MNI) involves a two-step process. The first step requires finding the most abundant element per taxon (White 1953). The articular ends of long bones, certain foot bones, and individual teeth are particularly useful in determining MNI for a given species (Gilbert 1980). Bones of the foot, such as the calcaneus and the astragalus, have a high survival rate in archeological contexts due to the density of the bone. The specimens are then separated into right and left sides (White 1953). Gilbert (1980) has noted that third molars are easily sided if a majority of the tooth is recovered. Similarly, the ends of long bones are easily separated into right or left, providing enough of the specimen is present.

The MNI counts for the block excavations at Canyonlands were calculated by determining the most abundant element for a species, counting the rights and lefts, and taking the largest number as the MNI for that species. Even though the MNI counts may be somewhat conservative (White 1953:397) or liberal (Binford 1978:70), they still reflect the dominant taxon/taxa at any given location. Although no measurements were made, the degree of fusion of the epiphyses of the most abundant elements was noted and did enter into the calculation of the MNI counts. Table 64 contains the number of identified specimens present (NISP) and minimum number of individuals (MNI) per taxon recovered from block excavations. The taxon code definitions are located at the end of the table.

At 42SA8502 (west), the minimum number of individuals for *Ovis candensis* was based on three distal tibiae, two left adult (epiphyses completely fused) and one right subadult (epiphyses just fused). The *Bos/Bison* MNI was based on two left metacarpals, one complete. For *Antilocapra/Ovis/Odocoileus* the MNI was based on the presence of adult, subadult and juvenile (epiphyses unfused) bones.

At 42SA8502 (east), the MNI for *Ovis canadensis* was based on three left distal calcanei fragments. The MNI for *Ovis* sp. was based on two right naviculo-cuboids, one complete, and two right calcanei, one complete. For *Antilocapra/Ovis/Odocoileus*, the MNI was based on the presence of adult and subadult bones.

At 42GR913, the MNI for *Sylvilagus* sp. was based on four right femurs—two proximal ends, two complete.

Table 64. Identifiable bone from block excavations.

Taxon	NISP	Percentage of site total	MNI	Percentage of site MNI
42SA8502 (west side)				
2	11	11.58	1	7.14
3	19	20.00	3	21.43
5	5	5.26	1	7.14
8	1	1.05	1	7.14
12	19	20.00	2	14.29
13	7	7.37	1	7.14
14	26	27.37	3	21.43
15	6	6.32	1	7.14
20	1	1.05	1	7.14
Totals	95	100.00	14	99.99
42GR913				
2	93	98.94	4	80.00
9	1	1.06	1	20.00
Totals	94	100.00	5	100.00
42SA8502 (east side)				
2	2	1.07	1	6.67
3	53	28.34	3	20.00
4	1	0.54	1	6.67
5	3	1.60	1	6.67
8	1	0.54	1	6.67
12	6	3.21	1	6.67
13	1	0.54	1	6.67
14	64	34.22	2	13.32
15	47	25.13	2	13.32
17	3	1.60	1	6.67
20	6	3.21	1	6.67
Totals	187	100.00	15	100.00
42SA16858				
2	6	20.00	2	20.00
6	3	10.00	1	10.00
7	1	3.33	1	10.00
10	11	36.67	2	20.00
11	4	13.33	1	10.00
14	2	6.67	1	10.00
15	2	6.67	1	10.00
18	1	3.33	1	10.00
Totals	30	100.00	10	100.00

Table 64. Concluded.

Taxon	NISP	Percentag e of site total	MNI	Percentage of site MNI
42SA8506				
3	1	8.33	1	12.50
7	3	25.00	1	12.50
10	1	8.33	1	12.50
14	2	16.67	1	12.50
15	2	16.67	1	12.50
17	1	8.33	1	12.50
19	1	8.33	1	12.50
20	1	8.33	1	12.50
Totals	12	99.99	8	100.00
42SA8512				
1	2	0.72	1	5.26
2	204	73.38	7	36.84
3	6	2.16	1	5.26
4	1	0.36	1	5.26
5	3	1.08	1	5.26
7	2	0.72	1	5.26
8	3	1.08	1	5.26
12	1	0.36	1	5.26
14	31	11.15	3	15.80
15	17	6.11	1	5.26
20	8	2.88	1	5.26
Totals	278	100.00	19	99.98

Key to Taxon Codes

1=*Lepus* sp. (jack rabbit)
2=*Sylvilagus* sp. (cottontail)
3=Ovis *canadensis* (bighorn sheep)
4=*Antilocapra americana* (pronghorn antelope)
5=*Odocoileus hemionus* (mule deer)
6=*Spermophilus* sp. (ground squirrel)
7=*Dipodomys* sp. (kangaroo rat)
8=*Neotoma* sp. (wood rat)
9=*Cynomys* sp. (prairie dog)
10=*Thomomys* sp. (northern pocket gopher)
11=Geomyidae (pocket gophers)
12=*Bos/Bison* (cow/bison)
13=*Bison bison* (bison)
14=*Antilocapra/Ovis/Odocoileus* (antelope/sheep/deer)
15=*Ovis* sp. (sheep)
16=*Bos* sp. (cow)
17=Mammal (medium to large)
18=Cricetidae (rats and mice)
19=Rodentia (rodents)
20=*Ovis aries* (domestic sheep)

At 42SA16858, the MNI for *Sylvilagus* sp. was based on two right mandibular fragments. One is a horizontal ramus with the third and fourth premolars and the first molar present. The other is a horizontal ramus with all teeth present. The MNI for *Thomomys* sp. was also based on two right mandibular fragments. One is the anterior end from the incisor to the fourth premolar and the other is a horizontal ramus with the incisor, fourth premolar, first molar, and second molar present.

At 42SA8512, the MNI for *Sylvilagus* sp. was based on seven complete calcanei—four right juvenile, one left subadult, and two left adult. The MNI for *Antilocapra/Ovis/Odocoileus* was based on the presence of adult, subadult, and juvenile bones.

ANALYSIS

Faunal assemblages from archeological sites can contribute a great deal of information about the subsistence activities and, under certain conditions, the organizational functioning of adaptive systems. Site complexity can be defined as the number and kinds of activities that took place at a site. This complexity is reflected through intra- and interassemblage variability. Placed on a continuum, sites can be highly complex, exhibiting high variability, or very redundant, exhibiting low variability. Therefore, functional relationships are represented by the types and numbers of artifacts present at a site, in addition to the types and numbers of structures and features. Generally, residential sites are more complex than task-specific sites; the former used for many activities, the latter for only one or two different purposes (Binford 1982).

There are different aspects of the faunal assemblage that can be studied to gain information about site function. One is the presence or absence of anatomical parts. For example, low-utility parts, such as mandibles and cranial elements, are frequently left at the kill locus due to their lack of meat. The heavier, epiphyseal portion of the long bones will also be left behind at the kill locus. Bones from other species will usually be highly fragmented and dispersed, with very few bones per animal. At butchery/special-processing loci, there will be more meat-bearing bone parts than nonmeat-bearing bone parts (Sivertsen 1980). The faunal remains of a residential locus will be biased towards ribs, vertebrae, pelves, femurs, scapulae and humeri. The presence of low utility parts, such as phalanges, metatarsals, tarsals, and carpals should be rare at residential sites (Thomas 1983:77).

Residential assemblages exhibit high diversity and low redundancy. On the other hand, low diversity and high redundancy characterize special-purpose locations (Binford 1978). This pattern of diversity and redundancy occurs in faunal assemblages also. Sivertsen (1980) describes the kill locus as containing bone remains dominated by those of one species, exhibiting low species diversity. Butchery/special-processing loci contain bone remains dominated by only a few species. Camp, multiple-activity, or terminal processing loci should contain a higher diversity of animal species present.

The species represented in an assemblage is another aspect that can add information about site function. Often species in common is the only attribute suitable for use in comparing faunal assemblages, if minimum numbers of individuals (MNI) are not calculated for the data, and individual types of elements are not listed. The numbers of identified specimens present (NISP) are usually reported, but are not particularly useful for direct comparisons between analytical units since specific quantities are not being considered (Chaplin 1971:70). Grayson (1984:28) notes that bone fragments are affected by butchering patterns which are largely determined by the size of the animal. Smaller animals are transported from the kill location whole, whereas larger animals are partially butchered on location, leaving low utility parts behind. Therefore, the importance of smaller animals in the assemblage is often exaggerated.

Sorensen's (1948) quotient of species similarity is useful for comparing faunal assemblages from archeological sites, because it uses one species in one population as the unit of comparison. The method groups populations on the basis of species similarity, with all species considered equally. The similarity between two populations (or groups of populations) is expressed by the Quotient of Similarity:

$$QS = \frac{2c}{a + b} \times 100$$

where *a* designates the number of species in one population, *b* the number of species in the other population, and *c* the number of species common to both. The value represents the percentagewise similarity of species between two populations in proportion to the similarity that is theoretically possible according to the number of species present. In other words, the number of actual coincidences is divided by the number of possible coincidences (Sorensen 1948:7). This method is an attempt to measure the similarity of an unclassified population to already established groups in order to place/classify the unknown as belonging to one such group.

In comparing two groups of populations the same formula is used, but *a* denotes the total number of species divided by the number of populations in one group, *b* the total number of species divided by the number of populations in the other group, and *c* the sum of the species common to both groups divided by the product of the number of populations in both groups (Sorensen 1948:8).

The quotient of species similarity (QS) values were calculated for faunal assemblages from selected sites at Black Mesa in Arizona and the Dolores area in Colorado and faunal assemblages from the block excavations at Canyonlands, comparing sites of "known" function with those of an unknown function. Comparative sites from Black Mesa and Dolores were chosen on the basis of type/complexity, age/affiliation, and percentage of taxa used (usually more than 50% of total taxa per faunal assemblage). The criteria for site complexity were set up independently of the faunal assemblage present at each site, with the underlying assumption being that longer, more complex occupations would produce larger, more diverse faunal assemblages.

Specimens identified to genus or above were used to calculate the quotient of similarity. Since the unidentifiable bone from Canyonlands was analyzed for taphonomic attributes, effects/affects, specimens that would usually be recognized simply as small, medium or large mammal, for example, were considered unidentifiable. Therefore, the remaining "identifiable" bones were identified to a more specific level. General taxon categories have been retained for the analysis of the assemblages from Black Mesa, causing a lower percentage of the total identified fauna to be used in calculating the quotient of similarity. The Dolores fauna have been identified at two levels. Fauna from many sites were identified only to class and the raw frequencies reported. Other assemblages were identified to genus or above with few, if any, specimens identified only to class. Fewer assemblages from Dolores than Black Mesa were used for comparison by the quotient of similarity, due to the level of analysis performed on the bone.

Table 65 contains QS values for the faunal assemblages of selected sites from the Black Mesa and Dolores archeological projects and the five block excavations at Canyonlands: 42GR913, 42SA8502, 42SA8506, 42SA8512, and 42SA16858 (see Appendix F for taxa present and frequency of occurrence of Canyonlands fauna). The sites are listed in descending order based on complexity. Comparative sites reported as residential bases, containing multiple occupations, and structures with accompanying features, are listed first. The next group of sites were occupied sporadically but were used as habitation loci; that is, they contained at least one habitation structure. At the end of the continuum are sites with no evidence of structures, and exhibiting relatively short-term usage; that is, limited activity loci designated as having either specific or amorphous functions.

PATTERNS FOR SITE USE

Patterning in the archeological record, such as the degree of species similarity between two faunal assemblages, may inform about the activities that produce patterning in the archeological record and/or the organizational differences or similarities among places in a system. Patterning may be the result of the repetition of use, the stability of use, or the spatial positioning of the home base. These variables are the consequences of the interaction between economic zonation and environmental geography which "...result in diagnostic forms of chronological patterning" (Binford 1982:6).

The focus of spatial patterning in human systems is usually some form of "home base" (Binford 1982:6). The presence of a territory surrounding the residential base was noted by Lee (1969) for the !Kung Bushmen in the Kalahari Desert. This area has been called the site territory (Higgs and Vita-Finzi 1972) or foraging radius (Binford 1982) and was defined as"..an area which is habitually exploited" by its inhabitants (Higgs and Vita-Finzi 1972:30). The terrain covered by occasional forays in search of raw materials for tools and other purposes has been termed the site catchment

Table 65. QS values for identifiable fauna from Black Mesa and Dolores sites versus Canyonlands sites.

	42GR913	42SA8502	42SA8506	42SA8512	42SA16858
Residential loci					
D:7:262	6.90	32.43	18.18	42.11	18.18
D:11:2068	18.18	33.33	30.77	45.16	38.46
5MT2336 (Kin Tl'iish)	10.00	35.71	16.67	41.38	16.67
5MT4683 (Singing Shelter)	7.69	29.41	13.33	34.29	13.33
D:11:2062	12.50	41.67	40.00	56.00	60.00+
D:11:316	33.33	30.00	37.50	50.00	37.50
D:11:3131	25.00	25.00	30.00	40.00	40.00
Special-purpose loci (structures present)					
D:11:2025	30.77	28.57	35.29	45.46	47.06
D:11:244	36.36	42.11	66.67+	60.00+	53.33
D:7:2064	33.33	42.86+	20.00	53.33	20.00
D:7:2090	66.67+	18.18	00.00*	16.67	28.57
5MT4650 (Hanging Rock Hamlet)	10.00	28.57	08.33	27.59	08.33
5MT4613 (Pozo Hamlet)	22.22	11.77	00.00	22.22	15.39
5MT2378 (Poco Tiempo Hamlet)	22.22	14.29	00.00	26.67	20.00
Special-purpose loci (no structures)					
D:11:3061	50.00	16.67	25.00	15.39	50.00
D:7:3119	50.00	16.67	00.00	30.77	50.00
D:7:3144	33.33	28.57	40.00	53.33	60.00+
D:11:2063	28.57	40.00	36.36	37.50	54.55

Note: All sites from Black Mesa have "D" designation; "5MT" are from the Dolores Archeological Project; and trinomials are from Canyonlands National Park.
* = *No species in common*
+ = Most similar assemblages

(Higgs and Vita-Finzi 1972). This corresponds to Binford's (1982) logistical radius. Extended site territory (Sturdy 1972:167) is described as that which is "...very seldom visited, but which supports the equivalent of the major resource...." Binford (1982:8) calls this area the extended range and notes that is it closely monitored "...with respect to resource distributions and changes in production."

Sites produced in the foraging radius are usually the remains of extractive tasks within a day's travel from the residential base and contain very little evidence of group maintenance. These sites are created by both foragers and collectors (Binford 1980). Sites within the logistical radius are produced by task groups on resource procurement forays farther than one day away from the residential base. These sites are positioned relative to resource distributions and are less ephemeral than foraging radius locations (cf. Binford 1982:8-9). They consist of the remains of kill sites, processing areas, field camps, and hunting stands, for example, and they are produced almost exclusively by collectors (Binford 1980).

Binford (1982) defines four sources for site variability: function, season, resource targets (subsistence base), and aggregation of functions. There is more overlap, both seasonally and functionally, at residential sites than logistical sites. Residential artifact distributions form a "...pattern of almost continuous overlapping multiple occupations of different types" (Binford 1978b:491). On the other hand, the artifact distributions that make up special-purpose locations are characterized by frequent site re-use. Binford (1982:16-18) suggests that shifts in the economic potential of places result in "...chronologically sequential change in assemblage content." There is rarely any overlap in seasonal use or in the structural role played in the overall subsistence strategy at special-purpose locations (Binford 1978b:490).

The faunal contents of special-purpose locations reflect the overall low diversity and high redundancy of fixed sites within a logistical radius. Faunal remains from residential locations vary considerably with the season of occupation.

> Residential sites are more flexible in their location and more variable in their content. Special-purpose locations are more discrete in their location and more redundant in their use and contents (Binford 1978b:491).

The differences in assemblages observed at special-purpose locations are likely to indicate a change in function, whereas differences observed at residential locations probably indicate a change in routine, season, etc. (Binford 1978b).

Although several sites may have been occupied at any one time in a mobile economy, it is difficult to tell which sites are contemporaneous (Higgs and Vita-Finzi 1972). This is true for the re-occupations of sites where both natural and cultural processes have considerably mixed archeological deposits (Binford 1982:16; Schiffer 1976). The effects of this type of variability are compounded by the movement of the residential base from one location to another, causing the foraging radius to become the logistical radius, with a hunting camp, stations, locations, caches, etc., being located on top of or adjacent to what was formerly the residential base (Binford 1978b:491). Associations among classes of artifacts may actually represent associations among different occupations, not the "... regular performance of sets of activities during any one occupation" (Binford 1982:17).

The faunal assemblages at such sites are therefore likely to be the result of the subsistence activities of several occupations, as well as the result of several different kinds of operations that were performed during one occupation. Faunal assemblages may be viewed as being made up of species components, for example a lagomorph versus a artiodactyl component, although these components are not necessarily mutually exclusive. Looking at the faunal assemblage in this way may aid in the interpretation of site function when a site has been extensively re-used.

SIMILAR FAUNAL ASSEMBLAGES

There is variation even between the most similar combinations of species in the assemblages with the highest QS values (see Table 65). This variation could be due to the different patterns of site use described by Binford (1978b, 1980, 1982). Table 66 lists the species represented in the most similar faunal assemblages from the comparative sample and the faunal assemblages from the block excavations at Canyonlands.

Table 66. Taxa present in the most similar faunal assemblages from sites at Canyonlands and Black Mesa.

	Sites*									
Taxa	1	2	3	4	5	6	7	8	9	10
Lepus	x		x	x		x	x			
Sylvilagus	x	x	x	x		x	x	x	x	x
Cynomys	x						x			
Thomomys					x		x	x		x
Dipodomys					x	x	x	x	x	x
Neotoma			x	x		x				x
Spermophilus								x		x
Spermophilus variegatus/Cynomys										x
Perognathus										x
Peromyscus										x
Canis							x			
Antilocapra americana			x			x				
Odocoileus hemionus			x			x				x*
Ovis canadensis			x	x	x	x	x			
Ovis/Antilocapra/Odocoileus			x		x	x	x	x	x	
Ovis			x		x	x		x	x	x*
Ovis aries (/Capra hircus)			x		x	x	x			
Bos/Bison			x			x				
Bison bison			x							
Bos taurus										x
Falco sparverius										x

* 1=42GR913
2=D:7:2090
3=42SA8502
4=D:7:2064
5=42SA8506
6=42SA8512
8=42SA16858
9=D:7:3144
10=D:11:2062

42GR913 vs. D:7:2090

The faunal assemblage in the sample with the most similar species content to that of 42GR913 is from D:7:2090. D:7:2090 is described as a seasonal processing station for agricultural products (Smith 1982). Fauna from both sites are very similar, with merely a greater density of *Sylvilagus* remains at 42GR913 than at D:7:2090. The presence of four *Sylvilagus* individuals at 42GR913 indicates a possible field camp situation, (see discussion of 42SA8512 below), versus D:7:2090 with only fragmentary *Sylvilagus* remains. In terms of the faunal assemblages, the two sites are similar in the broad sense of having limited, special-purpose location components.

42SA8502 vs. D:7:2064

D:7:2064 is described as a small habitation site exhibiting seasonal or intermittent use (Lebo 1981). The species content of the faunal components of 42SA8502 and D:7:2064 are not particularly similar, as evidenced by the relatively low QS value of 42.86. The faunal assemblage of 42SA8502 is dominated by artiodactyl remains and that of D:7:2064 is mainly lagomorph remains. This difference may reflect a variation in the type of activities that went on at the two locations, i.e., one could have been a hunting camp and the other could have been an agricultural processing camp/location. According to Andrews (1980:41), lagomorphs replaced artiodactyls as the main meat source on Black Mesa with an increasing reliance on agriculture. The presence of a majority of artiodactyls or any larger herbivores suggests that these remains were associated with the central function of one of the use components of the site, as opposed to serving a lesser function such as a supplemental food source while another activity was going on. The virtual absence of artiodactyls at D:7:2064, along with the presence of corn and other seeds, points toward a more agricultural focus for this site (Andrews 1980). The lagomorph component at 42SA8502 may or may not be contemporaneous with the artiodactyl component of the faunal assemblage. To add to the confusion, the artiodactyl component is split further to encompass a historic component, as evidenced by the presence of the domestic species, *Ovis aries* and *Bos*. From the species content of the faunal assemblage at 42SA8502, it can be assumed that the site served many purposes through time.

42SA8512 and 42SA8506 vs. D:11:244

The species content of the faunal assemblage from 42SA8512 is closest to that of the faunal assemblage from D:11:244 on Black Mesa. D:11:244 is reported to represent a series of temporally discrete occupations. Occupation of the site lasted year-round, based on hearth locations and size of the interior habitation areas. The site served as an agricultural activities location in summer and had an unknown winter function (Rynda et al. 1981). The faunal assemblages from these sites do appear very similar, since a majority of identified specimens present are from lagomorphs, although 42SA8512 has a much more varied group of medium artiodactyls. The large number of lagomorphs (eight individuals) present at 42SA8512 is unusual for a limited-use site and, discounting site re-use, would be more indicative of a residence or camp (Grayson 1984; Sivertsen 1980). Small to medium-sized animal remains are generally found at camps, because the carcasses were carried back whole (Sivertsen 1980). However, lack of structures makes it unlikely that the site served as anything more than a transitory camp for a procurement excursion, making the possibility of site re-use more feasible. The presence of a large and varied artiodactyl component along with the lagomorph component may indicate that 42SA8512 was used for both hunting and agricultural purposes (Andrews 1980:41).

The species content of the faunal assemblage from D:11:244 is also most similar to that of the faunal assemblage from 42SA8506. The quotient of similarity for these two assemblages is even higher than the value for the assemblages from D:11:244 and 42SA8512 (Table 65). Even though the latter two sites have more species in common, 42SA8506 has more of its total species in common with D:11:244. 42SA8506 is one of two out of 23 sites considered in this study where no lagomorph remains were found. This seems unusual for sites in this area and may be related to site function or seasonality, although Andrews (1980) has found that lagomorphs became the dominant species in faunal assemblages with the increased importance of agriculture on Black Mesa. The identifiable faunal inventory for 42SA8506 is considerably smaller than the one for D:11:244. However, the unidentifiable bone count from 42SA8506 is approximately 885 pieces (mainly medium to large mammal, although some may be human; see site description). This contrasts with only

one piece of unidentifiable bone at D:11:244. This unidentifiable bone component may represent a processing location of some kind.

42SA16858 vs. D:7:3144 and D:11:2062

D:7:3144 was occupied for only a short time and functioned as a limited- or special-activity site with a probable single occupation (Burgett 1982). The faunal assemblages from D:7:3144 and 42SA16858 appear to be very similar, but lagomorphs make up a much larger portion (approximately 50%) of the NISP at D:7:3144. 42SA16858 contains a greater amount of unidentifiable bone (about 185 pieces), although the exact numbers of unidentifiable bone at D:7:3144 are uncertain from the faunal inventory presented.

The species content of the faunal assemblage from 42SA16858 is also most similar to the species content of the faunal assemblage from D:11:2062, a multi-component residential site (Sink et al. 1982). D:11:2062 contains all the features described above for long-term, multiple-activity locations. The faunal assemblage from D:11:2062 contains more species than the assemblage from 42SA16858, but the faunal assemblage from 42SA16858 is quite varied for its size. However, it does not contain the small rodent genera (*Perognathus and Peromyscus*) and bird remains (*Falco sparverius*) found at D:11:2062, which are more typical of major residential occupations (Falk et al. 1980). 42SA16858 possesses the faunal characteristics of a short-term residence/base camp. The presence of some sort of storage facilities at this site (see Feature 40 description, p. 127-129) makes this interpretation even more plausible. However with no habitation structures present, it is doubtful that the site was occupied for very long at any one time, and it probably represents a series of short-term stays on the way to and/or from resource procurement trips.

CONCLUSIONS

The quotient of species similarity is useful for evaluating the species content of two faunal assemblages. However, the similarity of the faunal assemblages as whole units cannot be determined by this measure. The minimum number of individuals or some other quantitative measure and the numbers and kinds of skeletal elements present for each species are really essential, if the part played by the faunal assemblage in the site use history is to be assessed (see Binford 1978). Only broad patterns of functional similarity can be ascertained from the species present at a site, i.e., residential versus logistical locations, although some degree of specific site use may be evident from the faunal assemblage, especially at kill locations.

The faunal assemblages from the block excavations at Canyonlands are useful for identifying certain economic activities that occurred at these locations. However, the faunal assemblage as a whole does not necessarily represent the entire round of activities that may have occurred at these locations. Other artifact assemblages, in conjunction with faunal remains, are probably more useful in determining the central activity of these sites.

POLLEN AND MACROBOTANICAL REMAINS

INTRODUCTION

Pollen and macrofloral analysis at ten sites in Canyonlands National Park was designed to address several different elements of the paleoenvironmental and subsistence records. Pollen samples from the present ground surface were collected to characterize the modern pollen record with respect to the modern vegetation. Stratigraphic samples were collected from three sites to provide an accurate view of paleoenvironmental conditions in the vicinity of Gray's Pasture at Island-in-the-Sky during Anasazi occupation, and between that occupation and the present.

Pollen and macrofloral samples were also collected from various features in an effort to build a record of the vegetal portion of the subsistence base. The pollen and macrofloral records supply complementary information concerning plants that were gathered, processed, and consumed at these sites. In addition, numerous metates recovered at 42SA16858 were washed for their pollen content to further augment the subsistence record. Three vessels recovered at 42SA8506 and 42SA16858 were also washed for their pollen content, contributing additional data to the subsistence record. The examination of pollen adhering to working surfaces, such as metates, as well as storage surfaces, such as vessels, adds immeasurably to the interpretations of subsistence activities at these sites. Sampling these surfaces provides direct data concerning processing and storage activities by the occupants of these sites.

METHODS

The pollen was extracted from soil samples from excavation units in the Island-in-the-Sky district. A chemical extraction technique based on flotation was the preparation technique used for the removal of the pollen from the large volume of sand, silt, and clay with which they are mixed. This particular process was developed for extraction of pollen from soils where preservation has been less than ideal and pollen density is low.

Hydrochloric acid (10 percent) was used to remove calcium carbonates present in the soil, after which the samples were screened through 150-micron mesh. Sodium polytungstate (density 2.0) was used for the flotation process. All samples received a short (10 minute) treatment in hot hydrofluoric acid to remove any remaining inorganic particles. The samples were then acetolated for 3 minutes to remove any extraneous organic matter.

A light microscope was used to count the pollen to a total of 100 to 200 pollen grains at a magnification of 430x. Pollen preservation in these samples varied from good to poor. Comparative reference material collected at the Intermountain Herbarium at Utah State University and the University of Colorado Herbarium was used to identify the pollen to the family, genus, and species level, where possible.

Pollen aggregates were recorded during identification of the pollen. Aggregates are clumps of a single type of pollen, and may be interpreted to represent pollen dispersal over short distances, or the actual introduction of portions of the plant represented into an archeological setting. Aggregates were included in the pollen counts as single grains, as is customary. The presence of aggregates is noted by an "A" next to the pollen frequency on the pollen diagram.

Indeterminate pollen includes pollen grains that are folded, mutilated, and otherwise distorted beyond recognition. These grains are included in the total pollen count, as they are part of the pollen record.

Ground stone and vessels were washed at the Midwest Archeological Center with distilled water and dilute hydrochloric acid to recover any pollen from the ground surface. Concentrations of pollen from the ground surfaces may represent plants ground using manos and metates. The ground surfaces had no appreciable quantity of dirt adhering to them. The surfaces were washed with distilled water and dilute hydrochloric acid, and scrubbed with a brush to release all trapped pollen. The resulting liquid was saved, and processed in

a similar manner to the soil samples, with the exception that the zinc bromide separation was not used.

DISCUSSION

The pollen record from the seven sites is separated into two sections: environmental and subsistence. The environmental discussion presents data from samples of the present ground surface, as well as the stratigraphic columns. The pollen data from features, metate washes, and vessel washes are integrated with the macrofloral data from the same features and sites. Nine prehistoric sites and one historic site are represented in the macrofloral data base.

ENVIRONMENTAL POLLEN

Modern vegetation in the vicinity of Gray's Pasture includes six major types: blackbrush shrubland, pinyon-juniper woodlands, semi-desert grasslands, sagebrush—fourwing saltbush shrublands, salt-desert shrublands, and riparian tall shrublands, in order of relative importance or area covered (Loope, 1977:ix). Thick aeolian sands are noted to support grasslands almost exclusively. The most common grasses are needle-and-thread (*Stipa comata*), galleta (*Hilaria jamesii*), Indian ricegrass (*Oryzopsis hymenoides*), and blue grama (*Boutelous*) (Figure 14). Few shrubs are noted in the grasslands, and include winterfat (*Ceratoides lanata*, a Cheno-am), Mormon tea (*Ephedra viridis*), and rosemary mint (*Poliomintha incana*). Wavyleaf oak (*Quercus undulata*) is also associated with sand mounds occurring in this area (Loope 1977:48).

Gently sloping and flat surfaces with uniformly thin regolith are dominated by blackbrush (*Coleogyne ramosissima*). While blackbrush is dominant, galleta grass, shadscale saltbush (*Atriplex confertifolia*), and Mormon tea (*Ephedra torreyana*) were also recorded in this zone. Less common are Indian ricegrass, prickly pear cactus (*Opuntia* spp.), yucca (*Yucca angustissima*), and snakeweed (*Gutierrezia* spp.) (Loope 1977:66).

Pinyon-juniper woodland occurs in canyons and on benches that have little or no regolith deposit. Fissures in the rock concentrate precipitation, thus supporting these trees. *Pinus edulis* and *Juniperus osteosperma* are dominant in this zone. Shrubs noted also include mountain mahogany (*Cercocarpus montanus*), Oregon grape (*Berberis fremontii*), ash (*Fraxinus anomala*), serviceberry (*Amelanchier utahensis*), cliffrose (*Cowania mexicana*), squawbush (*Rhus trilobata*), snowberry (*Symphoricarpos longiflorus*), Bigelow sagebrush (*Artemisia bigelovii*), snakeweed, brickellbush (*Brickellia microphylla*), blackbrush, prickly pear cactus, yucca, Mormon tea, and fendlerbush (*Fendlera rupicola*).

Sagebrush-saltbush shrublands are common on the banks of the Green and Colorado Rivers. Benches along the rivers frequently also support rabbitbrush (*Chrysothamnus nauseosus*), prickly pear cactus, greasewood (*Sarcobatus vermiculatus*), pepperweed, (*Lepidium montanum*), saltgrass (*Distichlis spicata*), Indian ricegrass, sand dropseed (*Sporobolus cryptandrus*), tansy-mustard (*Descurainia sophia*), Bigelow aster (*Machaeranthera bigelovii*), yellow bee plant (*Cleome lutea*), and bluebur stickseed (*Lappula redowskii*) (Loope 1977:79-80).

Several species of saltbush (*Atriplex*) dominate the vegetation in low-elevation benches with thin regolith cover and/or clayey soil. Benches located along the Green and Colorado rivers are frequently covered with saltbush. Other shrubs include budsage (*Artemisia spinescens*) and galleta grass (Loope 1977:99, 104).

Pollen samples were collected from the present ground surface at several sites (42SA8506, 42SA8512, 42SA415, 42SA8503, and 42SA16858) (Table 67). These sites are located at the edges of grassland, blackbrush shrubland, and pinyon-juniper woodland zones. Site 42SA8503 is located farthest south and is near the boundary between grassland and pinyon-juniper woodland. The land below the steep talus slope to the west of the site is dominated by blackbrush vegetation. The pollen record from the present ground surface at this site is dominated by Cheno-am pollen. This pollen appears to be wind transported from the blackbrush and sagebrush-saltbush vegetation zones located along the Green River to the west of the site. Relative quantities of *Pinus* and *Juniperus* pollen are low at this site, as are *Artemisia* frequencies. The High-spine Compositae and Gramineae pollen frequencies are moderately high, reflecting the presence of rabbitbrush, snakeweed, asters, or other composites, as well as grasses in the vicinity of the site.

Site 42SA415 is located to the northwest of 42SA8503 at the edge of a pinyon-juniper woodland.

Table 67. Provenience of pollen samples from pollen columns and the present ground surface (PGS) at Canyonlands.

Sample No.	Stratum	Depth in cm below pgs	Description	Pollen Counted
42SA8506				
1		0	PGS, 3 m north of EX-142	200
2		0	PGS, 5 m south of EX-108	200
T191-3E	A	8-16		200
T191-4E	B	17-27		210
T191-6E	C	37-47		200
T191-9E	D (top)	67-77		240
T191-14E	D (base)	117-127		200
T191-16E	E (top)	137-147		200
T191-19E	E (base)	167-177		202
42SA8512				
3		0	PGS, near WX-273	200
4		0	PGS, near WX-273	200
42SA415				
5		0	PGS, near EX-292	200
6		0	PGS, near EX-292	200
42SA8503				
7		0	PGS, 5 m north of WX-219	200
8		0	PGS, 4 m north of WX-226	200
T236-30W	I	0-10		200
T236-32W	II	20-30	Cultural	200
T236-34W	III	40-50	Cultural	200
T236-37W	IV	70-80	Cultural	200
T236-39W	V	90-100	Cultural	201
T236-41W	VI	110-115		200
42SA16858				
9		0	PGS, 4 m north of EX-150	200
10		0	PGS, 2 m west of EX-145	200
T180-3E	I	0-10		200
T180-4E	II	10-20		200
T180-6E	III	30-40	Possibly cultural	200
T180-7E	IV	40-50	Possibly cultural	200
T180-9E	V (top)	60-70	Possibly cultural	200
T180-15E	V(base)	120-130		200

Samples from the present ground surface in this area are dominated by *Juniperus* pollen. *Pinus* pollen is noted to fluctuate in the two samples examined. Shrub and grass pollen is considerably lower at this site. Site 42SA8512, located to the northwest of 42SA415 in a blackbrush vegetation zone, displays a pollen record very similar to that of 42SA415. At this site *Pinus* pollen contributes most heavily to the pollen record, followed by *Juniperus*, *Artemisia*, and the Compositae. The Gramineae frequency is higher in one sample than the other from this site. Rosaceae pollen recovery was regular, and highest at sites 42SA415 and 42SA8512, although it did not exceed 2 percent.

Site 42SA8506 is located to the east of 42SA415 at the boundary of pinyon-juniper and grassland vegetation zones at the edge of Gray's Pasture. The pollen record from the present ground surface at this site exhibits moderate frequencies of both *Pinus* and *Juniperus* pollen. One sample contains a very large frequency of *Ephedra nevadensis*—type pollen, indicating proximity to Mormon tea shrubs. Other common elements of the pollen record include Cheno-ams, *Artemisia*, and Low- and High-spine Compositae. The Gramineae pollen frequency is relatively low at this site.

Site 42SA16858 is located inside the boundary of the grassland zone of Gray's Pasture. The pollen record from the present ground surface at this site is variable, with either Cheno-am or *Ephedra nevadensis*—type pollen dominating. The *Pinus* and *Juniperus* pollen frequencies are moderate at this site. The quantities of *Artemisia* and Low- and High-spine Compositae are low to moderate. The Gramineae pollen frequencies are slightly higher at this site than at 42SA8506. It is interesting to note that *Zea mays* pollen was observed in one present ground surface sample from this site. Depending on the location of the present ground surface sample, it may indicate agriculture in the vicinity of this site in Gray's Pasture, or possibly modern contamination, as corn cobs were recovered from a small historic corral at 42SA8515 (see Bye 1980:4-5; Hartley 1980:171).

Stratigraphic columns were sampled for pollen at sites 42SA8503, 42SA8506, and 42SA16858 (Tables 67 and 68). All three columns demonstrate relatively high frequencies of Cheno-am pollen in the lower subsurface deposits, declining to frequencies near those recovered from the present ground surface samples in the upper deposits. This decline in Cheno-am pollen frequency is accompanied by a slight rise in the arboreal pollen, specifically *Pinus* and *Juniperus* pollen. The pinyon-juniper woodland at Island-in-the-Sky is confined to rock outcroppings where the trees may take advantage of fissures in the rock, which serve to concentrate moisture. Very little soil or regolith is present in these areas. It is unlikely that the pollen record represents a reforestation at Island-in-the-Sky, because the vegetation zones are so closely associated with the substrata. It is more likely that the relatively large frequencies of Cheno-am pollen observed in the subsurface strata correlate with cultural deposits and represent disturbance of the ground through occupation.

High-spine Compositae pollen increases as Cheno-am pollen decreases, especially at sites 42SA8503 and 42SA16858. This may represent an increase in snakeweed towards the present. Gramineae pollen frequencies are relatively low in the subsurface strata, suggesting that grass may not have been as abundant during the Anasazi occupation as it is today.

At sites 42SA8503 and 42SA16858 a direct correlation may be made between the strata sampled and levels containing cultural artifacts at the site. The correlation at 42SA8506 is somewhat more tenuous, as this site is located in an active dune field, and the depths in the test unit sampled stratigraphically for pollen do not correlate directly with depths of the various cultural layers at the rest of the site. It is highly probable, however, that Strata C, D, and E correlate with the occupation of the site (Susan Vetter, personal communication 1989).

There is no evidence in the stratigraphic columns to postulate paleoenvironmental conditions. Samples were collected one per stratum, rather than at 10-cm intervals. Close-interval sampling is necessary to attempt paleoenvironmental reconstructions. The present data base provides basic information concerning gross changes in vegetation, such as an increase in Cheno-ams during the Anasazi occupation of this area. This increase is most likely tied to disturbance of the land by the occupation, rather than being indicative of changing environmental conditions. The stratigraphic columns sampled were located near or at the edges of archeological sites. The vegetation in this area was thus subject to considerable disturbance during occupation.

Table 68. Pollen types observed in samples from stratigraphic columns.

Scientific Name	Common Name
ARBOREAL POLLEN:	
Abies	Fir
Alnus	Alder
Juniperus	Juniper
Picea	Spruce
Pinus	Pine
Pseudotsuga	Douglas fir
Quercus	Oak
Salix	Willow
NON-ARBOREAL POLLEN:	
Cheno-ams:	Includes amaranth and pigweed family
Sarcobatus	Greasewood
Cleome	Beeweed
Compositae:	Sunflower family
Artemisia	Sagebrush
Low-spine	Includes ragweed, cocklebur, etc.
High-spine	Includes aster, rabbitbrush, snakeweed, sunflower, etc.
Liguliflorae	Includes dandelion and chickory
Cruciferae	Mustard family
Cyperaceae	Sedge family
Ephedra	Mormon tea
Eriogonum	Wild buckwheat
Euphorbia	Spurge
Gramineae	Grass family
Onagraceae	Evening primrose family
Opuntia	Prickly pear cactus
Rhamnaceae	Buckthorn family
Rhus radicans	Poison ivy
Rosaceae:	Rose family
Cercocarpus	Mountain mahogany
Saxifragaceae	Saxifrage family
Scrophulariaceae	Figwort family
Shepherdia	Buffaloberry
Solanaceae	Potato/tomato family
Sphaeralcea	Globe mallow
Typha	Cattail
Zea	Maize, corn

ETHNOBOTANIC REVIEW

The ethnobotanic literature provides evidence of historic-era exploitation of numerous plants, both by broad categories, such as greens, seeds, roots, and tubers, etc., and by specific example, i.e., seeds that were parched and ground into meal, formed into cakes, and fried in grease. Repetitive evidence of the exploitation of resources indicates a widespread utilization and strengthens the possibility that the same or similar resources were used in prehistoric times. The ethnobotanic literature serves only as a guide indicating that the potential for utilization existed in prehistoric times, not as conclusive evidence that the resources were used. Pollen and macrofloral remains, when compared with the material culture (artifacts and features) recovered by the archeologists, become indicators of use.

Ethnobotanic references provide descriptions of the utilization of various native and cultivated plants by modern Pueblo Indians. Brief descriptions of these plants serve as a background for the interpretation of the pollen and macrofloral records from the Island sites.

Celtis (hackberry) fruits may be eaten raw, cooked, or dried. The thin pulp is tasty and sweet and attracts birds and small animals.

Juniperus is noted to have been used as a fuel and for construction, and the bark was used as tinder (Colton 1974:330; Robbins et al. 1916:39-40; Stevenson 1915:55, 93; Whiting 1939:62). In addition, the berries were eaten with piki bread, cooked in stew, boiled, roasted, or dried and ground to form a meal, which may be used in various cakes (Colton 1974:330; Cushing 1920:243,255; Whiting 1939:62). A medicinal tea was also made from the leaves (stems or scales) (Beaglehole 1937:71; Robbins et al. 1916:39-40; Stevenson 1915:55,93).

Pinus (pinyon pine) nuts are noted to have been eaten. Roasting preserved the nuts for storage and prepared the nuts for grinding into meal, which was mixed with cornmeal (Colton 1974:347; Gallagher 1977:37-39; Nequatewa 1943:18; Whiting 1939:63). A bumper crop occurs approximately every seven years. Nuts may be harvested in the fall or early winter. While they may be eaten raw, pine nuts were usually roasted prior to storing. Ground nuts were used in a variety of ways: including to thicken soup, to make cakes, and mixed with the pulp of yucca fruits. In addition, both pinyon and ponderosa pine needles may be used to make tea (Harrington 1967:323-325). Pine was also used as a fuel (Robbins et al. 1916).

Cheno-ams are a group of plants that include the goosefoot family (Chenopodiaceae) and pigweed (*Amaranthus*) and were exploited for both their greens (cooked as potherbs) and seeds. The greens are most tender when young, in the spring, but may be used at any time. The greens may be harvested and cooked either alone or with other food, or be packed around yucca fruits when they are baked. The seeds were ground and used to make a variety of mushes and cakes and were frequently mixed with cornmeal. The seeds are usually noted to have been parched prior to grinding. *Chenopodium* and *Amaranthus* are both weedy annuals capable of producing large quantities of seeds. *Atriplex*, which occurs as both an annual herb and perennial shrub, may also be exploited for both its greens and seeds. Saltbush leaves have a salty taste and have been used as a seasoning. Saltbush seeds do not ripen until mid-fall and may remain on the shrubs throughout the winter into the next growing season (Chamberlin 1964:366; Colton 1974:300; Cushing 1920:244-245; Gallagher 1977:12-16; Harrington 1967:55, 57, 71; Nequatewa 1943:19; Schopmeyer 1974; Stevenson 1915:66; Whiting 1939:73-74). The greens are available and most succulent during the spring and early summer, although they may be gathered and used at any time during the growing season. The seeds may be harvested in the late summer and fall.

Cleome is used both as a food and a pottery paint. The young plants are usually gathered and boiled for food. Both the young and older plants may be gathered and the entire plant boiled until the water is thick and black. This fluid is then dried and made into cakes, which keep an indefinite period. The cakes may be soaked in water to be used for paint, or soaked and then fried in grease to be eaten. The seeds may also be gathered and ground into meal, although utilization as a potherb appears to have been more common (Harrington 1967:72; Robbins and Marreco 1916:58-9; Stevenson 1915:69, 82; Whiting 1939:77-8). *Cleome* is noted to have been allowed to grow in gardens with cultivated plants. At Hano it was named with the three chief cultivated plants: corn, pumpkin, and cotton (Whiting 1939:77-8). As with Cheno-ams, the greens

may be harvested at any time during the growing season, although they would be more tender during the spring and early summer. The seeds ripen in the late summer and fall.

Helianthus (sunflower) is a member of the morphological pollen group of High-spine Compositae. Sunflower seeds are very rich in oil, and may be ground into paste for batter or roasted and eaten. Other members of the Compositae family were used in a variety of ways, including medicinally and as food. Rabbitbrush is noted to have been used as one of the four kiva fuels. The plant is also a source of both yellow and green dye. Snakeweed is used medicinally and also as a paho (prayer stick) decoration (Whiting 1939:94-99).

Ephedra is noted to have mainly medicinal uses. A beverage may be made from the dried stems and flowers. The tea may be used as a remedy for diarrhea, although the most frequently mentioned cure is for syphilis (Colton 1974; Robbins et al. 1916; Stevenson 1915; Whiting 1939).

Members of the Gramineae (grass family) are noted to have been exploited for their seeds, which were ground and used for a variety of mushes, bread, and cakes. *Sporobolus* and *Oryzopsis* appear to have been the most widely used (Colton 1974:338, 365; Cushing 1920:219,253-4; Whiting 1939:65). Various grasses were used in the manufacture of or to decorate pahos (prayer sticks) (Whiting 1939:65-66). Grass seeds mature at various times, with *Oryzopsis* (Indian ricegrass) being among the earliest (available early in the summer), and *Sporobolus* (dropseed) not available until fall.

Members of the Liliaceae family that are most commonly exploited include *Allium* (wild onion), *Calochortus* (sego lily), and *Yucca* (yucca). Wild onions may be consumed raw or used as flavoring, and may be dried for preservation (Beaglehole 1937:69; Cushing 1920:227; Nequatewa 1943:20; Robbins et al. 1916:53, 110: Whiting 1939:70). Sego lily roots are eaten, frequently raw, and the seeds and flowers may be ground to make "yellow pollen" (Colton 1974:297; Whiting 1939:70).

Opuntia (prickly pear cactus) fruits were eaten, frequently boiled. The fruits may also be dried and ground into meal. The pads or joints of prickly pear cactus were also boiled and eaten, frequently with syrup (Beaglehole 1937:70; Nequatewa 1943:18-9; Robbins et al. 1916:62; Stevenson 1915:69; Whiting 1939:85-6). Prickly pear fruits ripen during the summer and fall, whereas the pads may be harvested at almost any time of year.

Plantago (plantain) seeds have been referred to as Indian wheat, as they have come to be used as a recent substitute for an Old World species of Plantago. The seeds may have been ground into flour. *Plantago* seeds are mucilaginous when wet, and may cement the sand together, as they frequently occur in abundant quantity (Kearney and Peebles 1960:802-803). The seeds ripen during the summer.

Rumex (dock or sorrel) may be used as a potherb, or the seeds may be ground into meal. The root has also been recorded as being used as a dye, and medicinally for colds. The roots also may be ground to a powder before being applied (Kearney and Peebles 1960:243; Stevenson 1915:59; Whiting 1939:73). Again, the greens are most readily available and are more tender early in the growing season, while the seeds ripen later in the summer.

Shepherdia (silverberry and buffaloberry) bear edible fruit. These fruits were sometimes eaten raw, although they were more often cooked into a sauce used to flavor buffalo meat, hence the common name. When fresh, the fruits may be ground, seeds and all, and shaped into patties, which may then be dried. The dried berries may also be used to make a beverage. In addition, the berries are noted to have been dried for winter use (Harrington 1967:282-285). *Shepherdia argentia* (silverberry) grows along streamsides.

Members of the Solanaceae family, primarily *Solanum* and *Physalis*, were exploited for food. The berries of both plants are edible, as are the roots of *Solanum* (Robbins et al. 1916:59,70-3; Whiting 1939:90). Wild potato (*Solanum*) is noted to have been allowed to grow as a weed in otherwise carefully tended agricultural plots (Whiting 1939:16).

Typha is a rich source of nutrients. Steward (1938) and Chamberlin (1964) note the utilization of cattail as food, and Harrington (1967) describes the use of both pollen and the seed-like fruits of cattail as food resources. The young pollen-producing flowers may be stripped from the spikes, or the pollen may be removed by shaking the mature flowers. The resulting flowers

and/or pollen may be mixed with flour. Flour made from cattail roots, which are best harvested in the fall, is similar with respect to quantities of fats, proteins, and carbohydrates to flour obtained from wheat, rice, and corn (Harrington 1967).

Cucurbita (squash) is a cultivated plant that has frequently been described as forming part of the cultivated trio of corn, beans, and squash used by Southwestern Indians. Both squash fruits and flowers may be consumed. The fruits may be prepared in a variety of ways, including boiling, frying, stewing, and drying for later use. Squash blossoms may be made into pats or cakes, or used medicinally in conjunction with the seeds. The seeds may also be roasted and eaten, or used to oil piki stones (Cushing 1920:228; Robbins, Harrington, and Freire-Marreco 1916:100-102; Stevenson 1915:44-45, 66-67; Whiting 1939:93).

Phaseolus is listed as a staple food of historic Pueblo Indians. Most beans were thrashed upon harvesting. Beans may be cooked in a variety of ways, including being boiled and fried. Crushed boiled beans may be mixed with mush and wrapped in corn husks. Beans may also be added to meat stews (Robbins et al. 1916:100; Stevenson 1915:69-70; Whiting 1939:80-82).

Zea has been an important cultivated food, for which innumerable ways of preparation exist. The kernels may be parched, soaked in water with juniper ash, and boiled to make hominy. Dried kernels may be ground into meal, which is used as a staple. Cornmeal may be colored with *Atriplex* ashes. Black corn is used as a dye for basketry and textiles and as a body paint. Whole ears may be boiled and eaten. Corn is frequently husked immediately upon harvesting, limiting the quantity of corn pollen introduced into archeological proveniences. Seed corn retains a few inner husks, and clean husks are saved for smoking and other uses, such as wrapping food. The ordinary ears are allowed to dry on the roof. Ristras of corn may be hung inside from the roof (Cushing 1920:264-7; Robbins, Harrington, and Freire-Marreco 1916:83-93; Whiting 1939:67-70). "Corn appears in virtually every Hopi ceremony either as corn meal, as an actual ear of corn or as a symbolic painting" (Whiting 1939:67).

CULTURAL SAMPLES

Pollen and macrofloral samples were collected from features, ground stone, and vessels at 42SA415, 42SA8500, 42SA8502, 42SA8503, 42SA8506, 42SA8512, 42SA8515, 42SA16858, 42GR913, and 42GR2025 (Tables 69, 70, and 71). The pollen and macrofloral records from these sites will be discussed on a site-by-site basis below. In prehistoric sites it has become most acceptable to consider only charred seeds for the interpretation of a feature and utilization of resources (Minnis 1981). Few seeds live longer than a century, and most for a much shorter time period (Harrington 1972; Justice and Bass 1978; Quick 1961). It is presumed that once the seeds have died, decomposing organisms act to decay the seeds. The following discussion focuses on charred material, although the presence of uncharred remains are indicated on the accompanying table (Table 72).

42SA415

The Willow Seep site is located to the southeast of 42SA8512 (the Alcove Spring site) at the intersection of pinyon-juniper woodland and *Coleogyne* shrubland vegetation zones. The pollen record at this site consists of two samples from Feature 50, a slab-lined hearth. These samples (T292-9E and T292-10) (Table 72) were collected behind different slabs in the hearth. The pollen record displays considerable variation, with the dominant pollen type being either Cheno-ams or High-spine Compositae pollen (Table 72). Gramineae pollen is highest is sample T292-10. The large quantity of Onagraceae pollen suggests that a member of the primrose family was growing at this location at the time the hearth was lined. Collection of pollen samples behind slabs in the hearths provides more data concerning the local vegetation from local pollen rain at the time the feature was constructed and/or the pollen record already in the soil than it does about subsistence activities in the hearth.

A macrofloral sample was also analyzed from Feature 50. This sample did not contain any charred seeds, although *Juniperus* charcoal was noted to be dominant, and Rosaceae charcoal sub-dominant. It is probable that the Rosaceae charcoal represents *Coleogyne*. *Coleogyne* leaves were present from the modern environment (Table 72).

Table 69. Provenience of pollen samples from features at Canyonlands.

Sample No.	Feature No.	Date of Feature	Feature Description	Pollen Counted
42SA8502				
T102-88W	26	AD 1420-1655	Fire-reddened earth	100
42SA8506				
T97-191E	37	AD 585-900	Ash (F 37 in F 36)	100
42SA16858				
T146-60E	35	AD 610-1020	Ash from interior	205
T146-74E	35	AD 610-1020	Burned clay	102
T173-14E	41		Slab-lined shallow cist, burned clay	200
T173-17E	41		Slab-lined shallow cist, beneath basal slabs	200
42SA8500				
T269-10E	46	AD 65-430	Slab-lined hearth, behind slabs	Insuff
T269-11E	46	AD 65-430	Slab-lined hearth, behind slabs	100
T269-12E	46	AD 65-430	Slab-lined hearth, behind slabs	100
T269-13E	46	AD 65-430	Slab-lined hearth, behind slabs	100
T271-34E	47	1095-790 BC	Slab-lined hearth, behind slab	100
T271-35E	47	1095-790 BC	Slab-lined hearth, behind slab	Insuff
T271-32E	47	1095-790 BC	Slab-lined hearth, behind slab	Insuff
T271-33E	47	1095-790 BC	Slab-lined hearth, behind slab	100
42SA415				
T292-9E	50	410 BC-AD 15	Slab-lined hearth, behind & under slabs	
T292-10E	50	410 BC-AD 15	Slab-lined hearth, behind & under slabs	100
T292-11E	50	410 BC-AD 15	Slab-lined hearth, behind & under slabs	Insuff

Table 70. Provenience of pollen samples from metates and vessels at Canyonlands.

Sample No.	Vessel Code/ Feature No.	Dating Information	Sample Description	Pollen Counted
42SA16858				
T147-41E(W)	GH		Corrugated vessel wash (GH)	100
T147-60E	GH	Mesa Verde	Soil from outside vessel	200
T147-61E	GH	Corrugated	Soil from interior of vessel (lower half)	200
T168-80, 103E(W)	GF	PIII B/W	Complete olla wash (GF)	200
T173-39E	GF/F. 40	PIII B/W	Soil from interior of olla	200
T168-105E	GF/F. 40	PIII B/W	Soil/ash beneath olla	200
T172-31E(W)			Metate fragment wash	100
T172-32E			Soil under metate (T172-31E)	200
T172-29E(W)			Metate wash (2 frags)	200
T172-30E			Soil under metate (T172-29E)	200
T166-36E(W)			Metate wash, in west wall	200
T166-37E			Soil under metate (T166-36E)	200
T165-37E(W)			Metate fragment (fit) wash (T173-19E)	200
T173-20E			Soil under metate (T173-19E)	200
T147-44E(W)			Metate wash, in NW corner	200
T147-47E			Soil from trough of metate (T147-44E)	200
T147-48E			Soil under metate (T147-44E)	201
T165-46E(W)			Metate wash, in west wall	200
T172-25E			Soil under metate (T165-46E)	200
T173-19E(W)			Metate frags (fit) wash (T165-37E)	200
T165-38E			Soil under metate (T165-37E)	200
T173-48E(W)			Metate fragment wash	200
42SA8506				
T104-8E(W)	DF	Kayenta aff. Corrugated	Complete soiled vessel wash	100
T104-16E	DF	Kayenta aff. Corrugated	Soil from pedestal beneath vessel	100
T104-17E	DF	Corrugated	Soil from inside vessel (lower half)	100
42SA8500				
T271-21E(W)	F. 47		Metate fragment wash, part of slab lining of F. 47	Insuff
T271-22E	F. 47	1095-790 BC	Soil behind metate (T271-21E) which served as slab in	200

Table 71. Provenience of macrofloral samples from Canyonlands.

Feature No.	Date of Feature	Feature Description
42SA415		
50	410 BC - AD 15	Slab-lined hearth
42SA8500		
45	AD 1425-1660	Shallow charcoal stain
46	AD 65-430	Slab-lined hearth
47	1095-790 BC	Slab-lined hearth
42SA8502		
6	AD 1425-1655	Irregularly shaped charcoal stain
6	AD 1425-1655	T54-22E
7	AD 1235-1415	Basin-shaped hearth
8		Irregularly shaped charcoal stain
10		Basin-shaped hearth
11		Anomalous dark stain
14	AD 1655-1950	Dark circular charcoal stain
16		Shallow, irregularly shaped charcoal stain
17		Amorphous charcoal stain
26	AD 1420-1655	Oval-shaped charcoal stain
26	AD 1420-1655	Macrofloral, T93-11W
31		Amorphous charcoal stain
42SA8503		
T255-2E		Seeds recovered 30-35 cm below surface
42SA8506		
33	AD 895-1195	Semi-circular configuration of burnt logs and charcoal stain
34	AD 620-895	Partial human burial overlain by sandstone slabs
36	AD 585-900	Basin-shaped charcoal stain
36	AD 585-900	T97-174E/259E, top of F. 36
37		Irregularly shaped ash concentration in F. 36 (a basin-shaped charcoal stain)
39	AD 875-1055	Large pit possibly intrusive into F. 32
T96-6E		Seeds removed from top 5 cm of unit
T108-56/78E		Seeds removed from area of human bone (F. 34) articulated beneath sandstone slabs
T109-20E/31E		Charcoal in F. 34
42SA8512		
56	AD 1345-1650	Basin-shaped ash and charcoal lens
56	AD 1345-1650	Macrofloral, T290-27W
56	AD 1345-1650	Macrofloral, T295-22W, top of feature
T295-23W		Macrofloral, top of bedrock 50 cm south of F. 56
42SA8515		
FS81-4W		Macrofloral, historic corral, prehistoric lithic scatter, 200 m north of 42SA16858
FS81-5W		Macrofloral, historic corral, prehistoric lithic scatter, 200 m north of 42SA16858

Table 71. Concluded.

Feature No.	Date of Feature (AD/BC)	Feature Description
42SA16858		
35	AD 610-1020	
35	AD 610-1020	Macrofloral, T146-79E
40		Interior of olla, compares to T168-80, 103E pollen
40		Macrofloral from pit that contained olla or from olla itself from 90-95 cm bd, outside sherd T168-102E
T130-15E		Seeds recovered at 25-30 cm
42GR913		
1	770-405 BC	Shallow basin-shaped charcoal stain
3		Irregularly shaped charcoal stain
42GR2025		
5	AD 900-1205	Irregularly shaped dark stain

Table 72. Macrofloral contents of samples from Island-in-the-Sky.

Feature No.	Identification	Part	Charred Whole	Charred Frag.	Uncharred Whole	Uncharred Frag.
42SA415						
50	*Pinus*	Needle				1
	Juniperus	Stem				4
	Coleogyne	Leaf			15	2
	Unidentified	Fruit w/pedicel			1	
	Unidentified	Leaf (veined			1	
	Unidentified	Bract				1
	Charcoal:					
	Juniperus dominant					
	Rosaceae sub-dominant					
	Insect fragments					104*
	Casings					X
42SA8500						
45	Conifer	Conescale				7
	Conifer	Anther base w/glumes				5
	Conifer	Anther				341*
	Conifer	Bark				X
	Juniperus	Seed			3	25
	Juniperus	Stem				71
	Juniperus	Berry			1	
	Pinus	Seed				5
	Pinus	Needle			9	254*
	Ambrosia	Fruit				1
	Amelanchier	Seed			1	2
	Chenopodium	Seed			2	7
	Compositae	Seed				2
	Compositae	Pappus				7
	Coleogyne	Leaf			1403*	592*
	Corispermum	Seed			1	
	Cruciferae	Fruit				2
	Gramineae	Seed			1	
	Oryzopsis	Seed				12
	Unknown AA	Seed			2	3
	Unidentifiable	Berry			1	
	Unidentifiable	Embryo			1	
	Unidentifiable	Fruit				1
	Unidentified	Floret			1	
	Unidentified	Leaf (veined)				6
	Unidentified	Bract				21
	Bone			X		
	Insect fragments					80
	Casings					X
46	Conifer	Conescale				3
	Conifer	Anther base w/glumes				7
	Conifer	Anther				207*
	Juniperus	Seed				2
	Juniperus	Stem				174
	Pinus	Seed				20
	Pinus	Needle				879*
	Coleogyne	Leaf				294*

Table 72. Continued.

Feature No.	Identification	Part	Charred Whole	Charred Frag.	Uncharred Whole	Uncharred Frag.
	cf. *Viola*	Seed			2	
	Unknown AA	Seed			1	
	Unknown FF	Seed			1	
	Unidentified	Pedicel				5
	Unidentified	Bract				4
	Charcoal: *Juniperus*					
	Insect fragments					1735*
47	*Juniperus*	Seed			1	
	Pinus	Needle				1
	cf. *Viola*	Seed			1	
	Charcoal: *Juniperus*					
	Flakes					1
	Landsnail					X
	Insect fragments					5
	Rodent feces			X		X
42SA8502						
6	Confer	Conescale		173+		
	Juniperus	Seed				1
	Pinus	Seed		63		11
	Pinus	Needle		62*		28*
	Cheno-am	Seed			56*	
	Colegyne	Leaf			3*	
	Gramineae	Seed			1	3*
	Helianthus	Seed		1		
	Physalis	Seed	1			1
	Unknown K	Seed	1			
	Unidentifiable	Seed		1		6
	Unidentifiable	Leaf				2
	Unidentified	Budscale				1
	Charcoal: *Juniperus*					
	Bone			X		X
	Flakes					X
	Insect fragments					473*
	Casings					X
T54-22E	Bone			X		
	Rocks					2
7	Conifer	Anther				3
	cf. *Juniperus communis*	Needle				1
	Juniperus	Seed		1		
	Juniperus	Stem				3
	Pinus	Needle				14

Table 72. Continued.

Feature No.	Identification	Part	Charred Whole	Charred Frag.	Uncharred Whole	Uncharred Frag.
	cf. Ulmus	Leaf			1	
	Ambrosia	Fruit				1
	Coleogyne	Leaf			4	9
	Gramineae	Seed				2
	Unidentifiable	Seed		1		4
	Unidentified	Leaf (veined)				2
	Charcoal:					
	Juniperus					
	Bone			X		X
	Insect fragments					131*
	Casings					X
8	Conifer	Anther				11
	Juniperus	Seed				2
	Juniperus	Stem				7
	Pinus	Needle				10
	Coleogyne	Leaf				33
	Compositae	Seed			1	
	Leguminosae	Seed			2	
	Oryzopsis	Seed				1
	Unknown M	Seed				1
	Unidentifiable	Seed				7*
	Charcoal:					
	Juniperus					
	Bone			X		X
	Flakes					X
	Insect fragments					22*
	Casings					X
	Rootlets					X
10	*Pinus*	Needle				3
	Juniperus	Stem				2
	Coleogyne	Leaf			1	1
	cf. Crataegus	Seed			1	
	Unidentified	Bract				4*
	Charcoal:					
	Juniperus co-dominant					
	Pinus co-dominant					
	Insect fragments					48*
11	*Pinus*	Needle		1		
	Unidentifiable	Berry		1		
	Unidentifiable	Seed		1		
	Unidentifiable	Berry		5		
	Unidentified	Pedicel base		1		
	Bone			X		X
	Insect fragments					5

Table 72. Continued.

Feature No.	Identification	Part	Charred Whole	Charred Frag.	Uncharred Whole	Uncharred Frag.
14	Conifer	Anther				2
	Juniperus	Seed		7		1
	Juniperus	Stem				2
	cf. *Pinus*	Seed				1
	Pinus	Needle				4
	Cheno-am	Seed			1	
	Coleogyne	Leaf				10
	Cruciferae	Fruit				1
	Gramineae	Seed			1	
	cf. *Viola*	Seed			1	
	Unidentifiable	Seed			1	
	Unidentified	Leaf (veined)				1
	Bone					X
	Animal hair (clumps)					3
	Flakes					X
	Insect fragments					77*
	Casings					S
	Rootlets					X
16	Conifer	Conescale				1
	Conifer	Anther				8
	Pinus	Needle				7
	Amelanchier	Seed				4
	Celtis	Seed				2
	Cheno-am	Seed				2
	Coleogyne	Leaf		1	6	28
	Corispermum	Seed				1
	Gramineae	Seed			1	
	Leguminosae	Seed			1	
	Oryzopsis	Seed				1
	Unidentifiable	cf. Seed				1
	Unidentifiable	Seed				2
	Charcoal: *Juniperus*					
	Bone			X		X
	Insect fragments					173*
	Casings					X
17	*Juniperus*	Seed				1
	Pinus	Needle		1		5
	Chenopodium	Seed			1	1
	Cheno-am	Seed	1			
	Coleogyne	Leaf			2	
	Unidentifiable	Seed		5*		
	Unidentified	Leaf (vennate)				1
	Charcoal: *Juniperus*					
	Flakes					X
	Insect fragments					74*

Table 72. Continued.

Feature No.	Identification	Part	Charred Whole	Charred Frag.	Uncharred Whole	Uncharred Frag.
	Casings					X
	Rootlets					X
26	*Juniperus*	Stem				3
	Pinus	Needle				16
	Unidentified	cf. Bract				1
	Coleogyne	Leaf			1	
	Unidentifiable	Berry		30*		
	Charcoal:					
	Pinus					
	Bone			X		X
	Flakes					X
	Insect fragments					66*
	Casings					X
26M	Charcoal:					
	Pinus	Dominant				
31	*Juniperus*	Seed				3
	Juniperus	Stem				6
	Pinus	Needle		2		
	cf. *Pinus*	Bark				X
	Compositae	Seed			1	
	Gramineae	Floret				1
	Gramineae	Seed			2	
	Unidentifiable	Embryo			1	
	Bone					X
	Flakes					X
	Insect fragments					109*
	Casings					X
42SA8503						
T255-2W	*Oryzopsis*	Seed	1349			
	Unknown AA	Seed			3	1
42SA8506						
33	*Pinus*	Seed		10		
	Pinus	Needle				2
	Coleogyne	Leaf			5	
	cf. *Crataegus*	Seed			1	
	Euphorbia	Seed			1	
	Gramineae	Seed			4	1
	Malvaceae	Seed		1		
	Oryzopsis	Seed				11
	Unidentifiable	Seed		2		
	Unidentifiable	Berry		2		
	Unidentified	Leaf (veined)				9
	Charcoal:					
	Juniperus dominant					
	Pinus rare					

Table 72. Continued.

Feature No.	Identification	Part	Charred Whole	Charred Frag.	Uncharred Whole	Uncharred Frag.
	Bone				X	X
	Flakes					X
	Insect fragments					565*
34	Cheno-am	Seed		3		2
	Gramineae	Seed	1		3	
	Iva	Seed	1			
	Opuntia	Seed		29		
	Zea mays	Cupule		4		
	Zea mays	Cupule w/spikelets		1		
	Unidentifiable	Seed		6		
	Charcoal: *Juniperus*					
	Bone			X		X
	Flakes					X
	Insect fragments					83*
36	Charcoal: *Juniperus*					
	Insect fragments					3
T97-174E/259E	Unidentifiable mass, non-plant			10+		
37	Chenopodiaceae	Seed		1		
	Charcoal: *Juniperus*					
	Bone					X
	Insect fragments					1
39	*Chenopodium*	Seed			2	1
	Cheno-am	Seed		1		1
	Coleogyne	Leaf				1
	cf. *Crataegus*	Seed			1	
	Gramineae	Seed			1	
	Zea mays	Cupule		14		
	cf. *Viola*	Seed			1	
	Unidentifiable	Seed		7		
	Unidentified	Leaf (veined)				2
	Unidentifiable	Seed			1	
	Insect fragments					12*
	Casings					X
T96-6E	*Amelanchier*	Seed			20	
T108-56/79E	*Zea mays*	Kernel		3		

Table 72. Continued.

Feature No.	Identification	Part	Charred Whole	Charred Frag.	Uncharred Whole	Uncharred Frag.
T108-95E	Charcoal: *Juniperus*					
T109-20E/31E	Charcoal: *Juniperus* dominant Diffuse porous rare					
42SA8512						
56	*Juniperus*	Seed	2	21		3
	Juniperus	Stem		4		
	Gramineae	Seed		35*	1	
	cf. *Lepidium*	Seed		1		
	cf. *Viola*	Seed			2	
	Unidentifiable	Seed		37*		
	Unidentified	Leaf (veined)				5
	Charcoal: *Juniperus* dominant *Fraxinus* rare					
	Bone			X		X
	Insect fragments					115*
	Casings					X
56M	*Juniperus*	Seed	3			
	Juniperus	Berry	8+			
56M	Unknown A				1	
T295-23W	*Pinus*	Seed				3
42SA8515						
FS81-4W	*Zea mays*	Cob				7
	Zea mays	Fused cupule				6
FS81-5W	*Zea mays*	Cob				1
42SA16858						
35	*Pinus*	Needle				1
	cf. *Pinus*	Seed				1
	Chenopodium	Seed	32*		1	3
	Cheno-am	Seed	2	5		10
	Cheno-am	Embryo			4	3
	Coleogyne	Leaf				1
	Gramineae	Seed			4	
	Plantago	Seed	1	2		
	Zea mays	Cupule		18		
	Zea mays	Spikelet base/Cupule glume	1			
	Unidentifiable	Embryo				1
	Unidentifiable	Seed		1		
	Bone			X		
	Flakes					X
	Insect fragments					64*
	Rootlets			X		

Table 72. Continued.

Feature No.	Identification	Part	Charred Whole	Charred Frag.	Uncharred Whole	Uncharred Frag.
35M	*Juniperus*	Seed		2		
	Pinus	Conescale w/two seeds		1		
40M	*Chenopodium*	Seed			3	4
	Cheno-am	Seed			2	2
	Cheno-am	Embryo			782*	325*
	Cruciferae	Embryo			5	1
	Gramineae	Seed				1
	Oryzopsis	Seed			1	4
	Zea mays	cf. Kernel		1		
	Zea mays	Fused cupule		5		
	Zea mays	Cupule	39	218*		
	Zea mays	Spikelet base/Cupule glume		136*		
	Unidentifiable	Seed		3		3
	Unidentifiable	Embryo				5 1
	Bone					X
	Flakes					X
	Pottery					X
	Insect fragments					434*
	Casings					X
	Rootlets					X
40M	*Phaseolus*	Seed	1			
T130-15E	*Oryzopsis*	Seed			111	3447+
	Oryzopsis	Embryo			6	12+
42GR913						
1	*Juniperus*	Seed				1
	Juniperus	Stem				15
	Chenopodium	Seed			1	
	Coleogyne	Leaf			1	
	Cruciferae	Fruit			2	1
	cf. *Viola*	Seed			1	
	Unidentifiable	Seed				1
	Unidentifiable	Fruit				1
	Unidentifiable	Flower or anther base				1
	Unidentified	Pedicel			1	
	Unidentified	Leaf (veined)			2	2
	Bone					X
	Flakes					X
	Insect fragments					19
	Casings					X
3	*Juniperus*	Stem				10
	cf. Bone					X
	Flakes					X

Table 72. Concluded.

Feature No.	Identification	Part	Charred Whole	Charred Frag.	Uncharred Whole	Uncharred Frag.
	Insect fragments					42*
	Casings					X
	Rootlets					X
42GR2025						
5	*Pinus*	Needle				1
	Unknown AA	Seed				3
	Unidentifiable	Seed		2		
	Bone			X		X
	Flakes					X
	Insect fragments					51*
	Casings					X

* indicates an estimated quantity X indicates the material was present but not quantified

42SA8500

Murphy Point site (42SA8500) is represented by pollen collected behind the slabs of two slab-lined hearths (Features 46 and 47). Fluctuations in pollen frequencies are noted in these samples, which may be associated with food processing activities if the slabs were not placed in the features immediately upon construction, and left undisturbed for the life of the feature. *Cleome* pollen is recorded in Feature 46 (sample T269-12) and an elevated frequency of *Opuntia* pollen was noted in sample T269-13 of the same feature. In contrast, Feature 47 contained no *Cleome* pollen, but did display a slightly elevated frequency of Cheno-am pollen accompanied by aggregates in sample T271-34 and an elevated frequency of Cheno-ams in sample T271-22, which was collected behind a metate used as a slab. The metate was placed with the trough facing into the feature, rather than out towards the wall. Sample T271-33 (Feature 47) exhibited an elevated Gramineae frequency. Sample T271-32 (Feature 47) contains the largest quantity of Liguliflorae pollen recorded in the project. It is possible that Cheno-ams, Liguliflorae, Gramineae, and *Opuntia* were all processed in this slab-lined hearth, provided this processing took place prior to lining the pit with slabs. It is more probable, however, that the *Cleome*, Cheno-am, *Opuntia*, and Liguliflorae pollen noted in these samples were introduced into the soil from local vegetation prior to digging the pit, or that the pit was dug in the summer when these plants were flowering, and pollen entered the feature as work progressed.

Macrofloral samples were also analyzed from Features 46 and 47. No charred remains other than charcoal were recovered from either feature. Both features yielded only *Juniperus* charcoal. In addition, a macrofloral sample was analyzed from Feature 45. This sample contained an abundance of uncharred remains, particularly *Coleogyne* from the local environment, but no charred remains, with the exception of bone.

42SA8502

The Neck site is represented by a single pollen sample and ten macrofloral samples.

Feature 6, an irregularly-shaped charcoal stain, yielded a radiocarbon age of AD 1425-1655. This feature contained a large quantity of charred conifer conescale fragments, as well as *Pinus* needle and seed

fragments. Single charred *Helianthus* (sunflower) and *Physalis* (ground cherry) seed fragments were also recovered. A single charred unknown seed was also recovered. All charcoal examined was *Juniperus*, indicating that juniper had been used as fuel. The charred macrofloral record indicates that pine nuts were harvested and processed in this feature, and that pine may have been used as fuel, although possibly only the small branches, as it is not represented in the charcoal record. It is possible that sunflower seeds and ground cherries were also roasted in this feature. A separate analysis of material from T54-22E yielded two pieces of burned bone.

Feature 7, a basin-shaped hearth, yielded a radiocarbon age of AD 1235-1415. Nearly all the macrofloral remains in the hearth were uncharred, indicating relatively modern intrusion. Only a single *Juniperus* seed fragment and an unidentifiable seed fragment were charred. Charred bone was also recovered, suggesting the possibility that this hearth was used to process animal remains. *Juniperus* charcoal was recovered from the feature, indicating that juniper was used as fuel.

Feature 8 was an irregularly-shaped charcoal stain. With the exception of some charred bone fragments, all remains recovered from this stain were uncharred, suggesting that they represent relatively modern intrusion, with the exception of *Juniperus* charcoal.

Feature 10 was a basin-shaped hearth that yielded only uncharred remains. Again, no information could be gathered concerning subsistence activities in this hearth. *Juniperus* and *Pinus* charcoal were codominant in this feature.

Feature 11 was an anomalous dark stain that was sampled for macrofloral remains. This feature yielded several unidentifiable charred fragments too small to identify. A single *Pinus* needle fragment was recovered from this stain, as were several unidentifiable berry fragments. Charred bone fragments were also recovered. It is possible that the berry fragments present were used in conjunction with meat processing.

Feature 14, a dark circular charcoal stain, yielded a radiocarbon age of AD 1655-1950. This very late feature contained primarily modern or uncharred remains, with the exception of a few charred *Juniperus* seed fragments. The presence of these seed fragments suggests that juniper seeds may have been processed, or that they were accidentally introduced if juniper was used as a fuel. Three small uncharred clumps of short animal hair were also recovered from this feature.

Feature 16 was a shallow, irregularly-shaped charcoal stain. All of the macrofloral contents of this feature were uncharred, representing relatively recent introduction. The only charred materials recovered were bone fragments and a single *Coleogyne* leaf fragment. *Juniperus* charcoal was recovered, indicating that juniper was used as fuel.

Feature 17 was an amorphous charcoal stain. This feature yielded a few charred remains, including a *Pinus* needle fragment, a whole and a fragment of a Cheno-am seed, and five charred unidentifiable seed fragments. *Juniperus* charcoal was recovered in this stain. It is possible that Cheno-am seeds were parched in this feature, or in the feature from which the ash and charcoal came.

Feature 26, an oval-shaped charcoal stain, yielded a radiocarbon age of AD 1420-1655. This feature contained uncharred macrofloral remains, some charred and uncharred bone, and *Pinus* charcoal. The presence of pine charcoal suggests that pine was used as a fuel. The pollen recovered from this feature reflects the natural vegetation. No evidence of subsistence activity was noted.

Feature 31 was an amorphous charcoal stain. Again, most of the macrofloral remains were uncharred, indicating relatively modern introduction. Two charred *Pinus* needle fragments were noted in the sample, which may have been accidentally introduced into a fire feature and charred, or been present on wood used as fuel.

42SA8503

The Murphy Corral site is represented by only a single macrofloral sample collected at T255-2W. This sample consisted almost entirely of uncharred *Oryzopsis* (Indian ricegrass) seed fragments. The fact that the seeds were uncharred indicates that they are modern. A few other uncharred seeds, which could not be identified, were also present.

42SA8506

The Dunes site is represented in the pollen record by samples collected from ash in Feature 37, as well as samples associated with a Kayenta-affiliated corrugated vessel (T104-8E; Figure 111). A pollen wash, as well as soil from inside and under the vessel, are represented. The macrofloral record includes samples from five features and two locations.

Feature 33, a semi-circular configuration of burnt logs and charcoal stain, yielded a radiocarbon age of AD 895-1195. This sample is represented by a macrofloral sample, which contained several charred items, as well as an array of uncharred remains. The charred remains include 10 *Pinus* seed fragments, a Malvaceae seed fragment, and several unidentifiable charred seed and berry fragments. Charred and uncharred bone fragments were recovered. *Juniperus* charcoal was dominant and *Pinus* charcoal was rare in this feature. The macrofloral record indicates that pine nuts, Malvaceae, other seeds and berries, and probably bone were processed in this feature.

Feature 34, a partial human burial overlain by sandstone slabs, yielded a radiocarbon age of AD 620-895. This burial contained several charred items, including Cheno-am seeds, a Gramineae seed, an *Iva* seed, numerous charred *Opuntia* seed fragments, and *Zea mays* cupule fragments. The presence of *Zea mays* cupule fragments suggests that corn may have been intentionally included in the burial, as may the other edible seeds. The recovery of 29 charred *Opuntia* seeds is unusual in features from these sites. It suggests that prickly pear fruits may have been more important in the diet than may be supposed through the recovery of pollen and charred seeds from features at these sites. *Juniperus* charcoal was also recovered. Both charred and uncharred bone fragments were also noted.

Feature 36, a basin-shaped charcoal stain, yielded a radiocarbon age of AD 585-900. The only macrofloral remains recovered from this stain were *Juniperus* charcoal fragments, which indicate that juniper was used as a fuel.

Feature 37 was an irregularly-shaped ash concentration located within Feature 36. The macrofloral record from this feature was sparse, containing only a single charred cf. Chenopodiaceae seed fragment and *Juniperus* charcoal. The pollen sample collected from Feature 37 displays pollen typical of the local vegetation, as well as *Zea mays* pollen, indicating that corn was processed in the feature. A moderately large quantity (5%) of *Rumex* pollen in this sample may also be associated with food processing activities.

Three pollen samples were collected from a Kayenta-affiliated vessel; one from the vessel fill, one from the soil beneath the vessel, and one as a wash of the vessel interior. The samples associated with the corrugated vessel all contained *Zea mays* pollen, which was most abundant in the sample collected from the soil beneath the vessel. It is important to note that the bottom of the vessel was broken, which probably allowed much of the contents of the vessel, pollen included, to wash into the soil beneath the vessel over the centuries that it was buried. The samples collected from the vessel wash and the soil inside the vessel exhibited elevated Gramineae pollen frequencies, suggesting that grass seed may have been stored in the vessel at one time. It is alternatively possible, however, that the grass pollen may represent locally abundant grasses. The pollen record indicates that the primary, and possibly only, contents of this vessel was corn.

Feature 39, a large pit that was possibly intrusive into Feature 32, yielded a radiocarbon age of AD 875-1055. This feature contained a charred Cheno-am seed fragment, as well as charred *Zea mays* cupule fragments and unidentifiable seed fragments. Charred *Zea mays* kernel fragments were recovered from a separate macrofloral sample (T108-56/79E) associated with this feature. In addition, *Juniperus* charcoal was recovered from T108-95E, and *Juniperus* charcoal was dominant in T109-20E/31E, both associated with this feature. A single piece of diffuse porous charcoal was noted in T109-20E/31E, indicating that a dicotyledonous tree or shrub was also used as fuel.

42SA8512

This site is represented by samples from Feature 56, a basin-shaped ash and charcoal lens near bedrock. This feature contained charred *Juniperus* seeds, seed fragments, and berries, and a relatively large quantity of charred Gramineae seed fragments, as well as a single charred *Lepidium* seed fragment. The variety of charred seeds recovered from this feature suggests that juniper berries, grass seeds, and pepperweed (*Lepidium*) seeds were all roasted. This feature contained primarily

Table 73. Inventory of cobs and cob fragments from 42SA8515.

Sample No.	Rows	Cupules	Diameter (mm)	Length (mm)	Rachis Seg Lg	Cupule Dimensions (mm) Length	Spikelet	Height
FS81-4W	16		12 (tip)	98	10.5	7.5	3.0	2.5
						8.0	3.5	2.2
						7.2	3.0	2.75
	2	14		24	11.0	8.0	3.0	2.4
						7.5	3.0	1.75
						8.2	3.0	2.4
	3	16.5		25	10.5	8.0	3.0	3.0
						8.0	3.0	2.0
						7.5	3.0	2.5
	2	18		33	11.0	7.0	3.0	1.75
						7.5	3.0	2.0
						7.5	2.75	2.4
	2	14.5		27	10.5	8.75	4.5	2.5
						8.5	3.2	2.0
						9.0	3.5	2.0
	1	8.5		30	10.5	8.0	3.75	2.0
						9.0	4.0	2.0
						8.0	3.75	2.2
	2	9.5		18	11.0	7.5	3.5	2.5
						8.0	3.5	2.5
						7.5	3.5	2.2
FS81-5W	18		21	59	9.75	5.0		2.4
						4.95		2.5
						5.5		2.75

Rachis Seg Lg = Rachis Segment Length in millimeters.

juniper charcoal, although one piece of ash (*Fraxinus*) charcoal was also recovered. This indicates that both juniper and ash were used as fuel.

42SA8515

Several corn cob fragments and some fused cupules were recovered at a historic corral. The cobs are assumed to be modern, through their association with the historic corral. Measurements are provided in Table 73.

42SA16858

Two features, two vessels, and eight metates were sampled for pollen at the Gray's Pasture site. In addition, two features and one location are represented by macrofloral samples.

Feature 35, a hearth exhibiting fire-reddened earth along its edges, was sampled in its ashy interior (sample T146-60E) and in the surrounding burned clay (sample T146-74E) for pollen. These samples exhibit elevated *Sphaeralcea* pollen, suggesting that globe mallow may have been a locally abundant plant. The presence of this pollen in similar frequencies in the

sample from the interior of the feature, as well as from the fire-reddened soil surrounding the hearth, which functions as a control sample, suggests that globe mallow was locally abundant rather than processed in the hearth. Pollen recovered from the fill of this hearth that was not noted in the burned clay sample includes *Cleome*, Solanaceae, and *Zea mays*. The pollen record suggests that beeweed, a member of the potato/tomato family, and corn were all processed in this hearth.

The macrofloral samples associated with Feature 35 contained charred *Chenopodium* and Cheno-am seeds and seed fragments, *Plantago* seed and seed fragments, *Zea mays* cupules and a spikelet base/cupule glume, and an unidentifiable seed fragment. In addition, charred and uncharred bones were recovered. The abundant charred macrofloral remains recovered in this feature indicate that *Zea mays* and *Chenopodium* were both processed, and that *Plantago* may have been processed, as well. Meat was probably also processed in this feature. Separate macrofossils were submitted for identification from this feature, and included *Pinus* conescale with seeds and *Juniperus* seed fragments. It appears that pine nuts and juniper seeds may also have been processed in this hearth.

Feature 41, a slab-lined pit that displayed signs of oxidation, contained hard, compacted mud, suggesting possible use as a mortar. It is possible that the contents of this feature do not reflect the original use of the feature (Vetter, personal communication 1989). The pollen record includes a sample collected from the burned clay (T173-14E) and one from beneath the slabs (T173-17E). Both samples exhibit elevated Cheno-am frequencies accompanied by aggregates. In addition, the sample of burned clay contained an elevated Gramineae pollen frequency, while the sample collected beneath the slabs contained *Zea mays* pollen. It is possible that Cheno-ams, grass seeds, and corn were all processed in this feature. The sample collected beneath the slabs was intended as a control sample, but contains evidence that pollen percolated into the soil between the slabs, and into the level below the slabs.

A Mesa Verde corrugated vessel (T147-41E; Figure 108) is represented by three samples, a wash of the interior, and soil from the interior and exterior of the vessel. The wash sample (T147-41E) contained *Cleome* and Liguliflorae pollen, as well as elevated Gramineae and *Zea mays* pollen frequencies. A small quantity of *Plantago* pollen was also noted in this wash sample. The only evidence of Celtis recovered at Island-in-the-Sky was recovered in the wash sample. It is possible that any of the gathered plants (*Celtis*, *Cleome*, Liguliflorae, Gramineae, and/or *Plantago*) were stored in the vessel. The pollen record indicates, however, that corn was definitely stored in the vessel. The large quantity (26 percent) of *Zea mays* pollen recovered in this wash is highly unusual. Almost all of the corn pollen grains were torn, which may happen in the grinding process, suggesting that ground corn was stored. In contrast, other pollen grains in the sample tended to be whole. Small quantities of *Zea mays* pollen were also recovered in samples from the soil inside and outside the vessel.

Feature 40, a pit containing an olla at its base, is represented by macrofloral samples. The macrofloral record contained abundant quantities of some uncharred remains, notable Cheno-am embryos. The charred remains included primarily *Zea mays* fragments representing kernels, cupules, fused cupules, and spikelet base/cupule glumes. Three unidentifiable seed fragments were also encountered. A separate macrofossil from this pit was submitted for separate identification. This specimen was a whole charred *Phaseolus* seed.

A Mesa Verde Black-on-white olla (T168-54-104E; Figures 106-107) with a broken bottom recovered from Feature 40, is also represented by three pollen samples; the pollen wash, and soil samples from the interior and beneath the base. The bottom of this vessel appears to have been broken prior to placement in the cist, as it was resting on a large pottery sherd. The pollen wash (T168-80-103E) of this vessel yielded small quantities of *Cleome*, Liliaceae, *Opuntia*, *Plantago*, *Cucurbita*, cf. *Phaseolus*, and *Zea mays* pollen. An elevated Gramineae pollen frequency was also noted. It appears that a number of gathered and cultivated foods may have been stored in this vessel, either sequentially or simultaneously. The sample collected from the soil beneath the vessel (T168-105E) also contained both *Cucurbita* and *Zea mays* pollen, which may have leaked through the broken bottom of the vessel. It is particularly interesting to note the complement of cultivated plants represented in the pollen record in this vessel.

The presence of pollen from corn, squash, and possibly cultivated bean, and the presence of charred corn and bean remains in the macrofloral sample indicate that cultivation at this site was not restricted to corn agriculture, but also included squash and beans. It is unusual to recover squash pollen, and even more rare to recover bean pollen in the archeological record. It is also very rare to recover charred bean remains. The rarity of these pollen and macrofloral types in the pollen record from this site should not be taken as an indicator of quantity of harvest, nor success of agriculture. Both plants (squash and bean) are insect pollinated, and the pollen may or may not be transported on the edible portions. The macrofloral remains are sufficiently large that when spilled they are easily picked up. Therefore, one does not expect to find as many charred remains of these foods, as of the small seeded items.

A macrofossil sample from T130-15E contained a large quantity of uncharred *Oryzopsis* (Indian ricegrass) seeds. These seeds appear to be relatively modern, as uncharred seeds are not expected to persist in the soil in open locations for centuries.

Eight metates were washed for their pollen content (Table 74). In addition, samples were collected beneath six of the metates. The soil contained in two metate troughs was also sampled. All metates were recovered upright, except one, which was inverted. Most of the samples collected beneath metates were removed from the soil on which the upright metate was situated. These samples were collected to function as controls. The eight metates were found concentrated in one section of the site, which may have functioned as a food processing area. It is probable that the metates were not laid down prior to the beginning of all food processing activities at the site. Rather, it is expected that the living surface beneath the metates will reflect past activities in that area.

Metate T172-31E did not exhibit a well-defined trough. The soil sample associated with this metate was collected beneath the upright metate. The wash of the trough area contained a small quantity of *Cleome* pollen, suggesting that beeweed seeds may have been ground. The sample collected beneath the metate contained a small quantity of *Zea mays* pollen, suggesting that corn may have been processed in this location.

The surface of Metate T172-29E was barely ground, and the accompanying soil sample was collected beneath the upright metate. The pollen wash displays a small quantity of *Zea mays* pollen. A slightly larger quantity of *Zea mays* pollen was present in the sample collected beneath the metate. The Cheno-am and Gramineae pollen frequencies are elevated in both samples representing the wash of the trough area and the soil beneath the metate. The pollen record indicates that this area was used to process foods before the metate was located here. In addition, it appears that the metate was used to grind corn, and may have also been used to grind Cheno-am and grass seeds.

Metate T166-36 was upright, and exhibited a deep trough. Pollen samples were collected as a pollen wash and soil sample inside the trough. Both samples contained slightly elevated Cheno-am frequencies, as well as a few small aggregates of Cheno-am pollen. Both samples also contained a small quantity of Liguliflorae pollen, which may or may not be related to food processing activities. In addition, the wash sample contained an elevated frequency of Gramineae pollen, suggesting that grass seeds may have been ground. The sample collected beneath the metate contained *Zea mays* pollen, which indicates that corn had been processed in this area prior to placing this metate on this spot.

Metate T165-37 is an upright metate fragment without a well-defined trough. The corresponding soil sample was collected beneath the metate. This metate fragment fits to T173-19, which was also upright. While this fragment had a good grinding surface, there was no defined trough. Again, the corresponding soil sample was collected beneath the metate. Both metate fragment washes exhibit a relatively large frequency of Cheno-am pollen, accompanied by at least a few aggregates. The wash of T165-37 contained small quantities of *Cleome* and *Typha* pollen, while T173-19 did not. The wash of T173-19 contained a small quantity of Liguliflorae pollen, while T165-37 did not. Both fragments exhibited slightly larger frequencies of *Ephedra* pollen than did the corresponding soil samples. If *Ephedra* had been processed, a much larger quantity of *Ephedra* pollen would be expected. Both wash samples also displayed slightly larger Gramineae pollen frequencies than did the corresponding soil samples, which may reflect grinding grass seeds. Leguminosae and Solanaceae pollen were recovered from both the wash and the soil

Table 74. Pollen types observed in samples from features and ground stone.

Scientific Name	Common Name
ARBOREAL POLLEN:	
Abies	Fir
Betula	Birch
Celtis	Hackberry
Juniperus	Juniper
Picea	Spruce
Pinus	Pine
Quercus	Oak
Salix	Willow
NON-ARBOREAL POLLEN:	
Caryophyllaceae	Pink family
Cheno-ams	Includes amaranth and pigweed family
Sarcobatus	Greasewood
Cleome	Beeweed
Compositae:	Sunflower family
Artemisia	Sagebrush
Low-spine	Includes ragweed, cocklebur, etc.
High-spine	Includes aster, rabbitbrush, snakeweed, sunflower, etc.
Other Compositae	Low-spine/High-spine
Liguliflorae	Includes dandelion and chickory
Cruciferae	Mustard family
Cyperaceae	Sedge family
Ephedra	Mormon tea
Eriogonum	Wild buckwheat
Gramineae	Grass family
Leguminosae	Legume or pea family
Liliaceae	Lily family
Onagraceae	Evening primrose family
Opuntia	Prickly pear cactus
Plantago	Plantain
Polemoniaceae	Phlox family
Anacarciaceae/Rhamnaceae	Sumac/Buckthorn families
Rhamnaceae	Buckthorn family
Rhamnus	Buckthorn
Rosaceae:	Rose family
Cercocarpus	Mountain mahogany
Rumex	Dock
Saxifragaceae	Saxifrage family
Shepherdia	Buffaloberry
Solanaceae	Potato/tomato family
Sphaeralcea	Globe mallow
Typha angustifolia	Cattail
Cucurbita	Squash, gourd
Phaseolus	Bean

sample from T165-37, but were not observed on T173-19. *Plantago* pollen was recovered from both wash samples. *Zea mays* pollen was recovered from the wash of T173-19 and from soil samples beneath both metate fragments. Corn was evidently processed in both areas prior to the metates being positioned, and was ground on this metate. The variety of other pollen, including Cheno-am, *Cleome*, Gramineae, *Plantago*, and *Typha*, suggests that several gathered resources may also have been processed using this metate.

Metate T147-44 is an upright metate that contained two manos and a black-on-white sherd on the grinding surface. The ground surface was well defined, although no trough was present. A soil sample was collected from the ground surface, and another beneath the metate. The wash and soil sample collected from the ground surface both contained very large quantities (19 percent and 16 percent, respectively) of *Ephedra* pollen. In contrast, the soil sample collected beneath the metate contained 3 percent *Ephedra* pollen. This suggests that Mormon tea was ground on the metate. This plant is used as a medicine, and may have been processed. The Gramineae pollen frequency was highest in the wash sample, a pattern noted on several other metates. In addition, *Opuntia* and *Typha* pollen were recovered only in the wash sample, while *Plantago* pollen was recovered from the soil collected from the trough. No *Zea mays* pollen was observed in the wash sample, although a moderate quantity (5 percent) was recovered from the soil sample from the ground surface. A small quantity of *Zea mays* pollen was recovered beneath the metate. Maize appears to have been ground both on the metate and in this location before the metate was positioned. Other gathered resources that may have been processed using this metate include *Ephedra*, Gramineae, *Opuntia*, *Plantago*, and *Typha*.

Metate T165-46 was found upside down, and was a classic deep-trough metate. The corresponding soil sample (T172-25) was collected beneath the trough. Both samples contained elevated quantities of Cheno-am pollen, although only a single aggregate of two grains was recovered from the soil beneath the trough. The wash sample contained a relatively large quantity (7 percent) of Gramineae pollen, indicating that grass seeds were ground. In addition, this sample contained small quantities of *Plantago* and *Shepherdia* pollen, suggesting the possibility that plantain seeds and buffaloberries were also ground. No *Zea mays* pollen was recorded in the wash sample, although it was recovered in the soil sample collected beneath the trough. Pollen recovered in the soil sample beneath the trough of this metate is probably indicative of use of the metate, since it was directly in contact with the grinding surface.

Metate T173-48 is represented by a single wash sample that exhibited small quantities of *Cleome*, *Opuntia*, and *Plantago* pollen, as well as a slightly elevated Gramineae pollen frequency and a large *Ephedra* pollen frequency. This metate also appears to have been used to grind Mormon tea, as was Metate T147-44. The absence of *Zea mays* pollen from the wash suggests that this metate may have been used to grind foods other than maize, such as the gathered resources *Cleome*, *Opuntia*, *Plantago*, and *Ephedra*.

The distribution of two gathered resources deserves separate mention. *Plantago* and *Typha* pollen were recorded almost exclusively in association with metate washes and trough samples from 42SA16858. This association provides rather strong evidence to suggest the exploitation of both resources, in spite of the fact that both pollen types are wind transported.

42GR913

This site is represented by macrofloral samples collected from Features 1 and 3. Feature 1 is a shallow basin-shaped charcoal stain. All remains recovered from this feature were uncharred, indicating relatively modern intrusion. Likewise, all of the remains recovered from Feature 3, an irregularly-shaped charcoal stain, were uncharred. No interpretations of subsistence activity were made at this site.

42GR2025

This site is represented by a single macrofloral sample collected from Feature 5. An irregularly-shaped dark stain, this feature contained two unidentifiable charred seed fragments, as well as charred and uncharred bone fragments. This feature appears to have been used to process meat, and may have included seeds in that processing.

REQUIREMENTS FOR CORN AGRICULTURE

Controlling factors affecting corn agriculture in the Four Corners area include snowfall, frost, and summer rain. The Hopi agricultural system is often used as a model of successful agriculture in the Southwest. Examples in the literature assume an ak-chin type of field, or one located at the point that run-off from a watercourse fans out upon reaching an approximately level area.

Planting dates are governed by snowfall and frost. During the winter months between November and March, cold weather is often accompanied by heavy snowfall. Conditions begin to warm in March, and spring may be a time of little precipitation. Most Hopi corn is planted between the latter two weeks in May and the first week in June. Leaves begin to appear on the surface between 10 and 14 days after planting, depending on the warmth of the soil. Frost after the leaves have opened will kill or severely damage the plant. Fields planted in gullies near the foot of a mesa may be protected from frost by nocturnal radiation from the gully walls. Frequently very little moisture is received until the end of June. Thunderstorms in July and August are common, and are often violent. In September, when the crops are harvested, the weather is usually sunny and dry (Bradfield 1971:4, 6). Hack (1942:20) notes that the Hopi plant corn from the middle of April (to harvest in July) to the middle of June. Corn may be harvested approximately 100 days after planting and used as green corn. The planting in the middle of April is a small one, with the main planting occurring between the middle of May and early June.

Snowfalls in later winter and early spring are necessary to saturate the ground during snowmelt. Seeds are planted 12-15 inches deep to take advantage of the moisture that survives at this depth. Germination is dependent on soil moisture and general soil warmth. Hopi corn is adapted to deep planting by having an elongated *mesocotyl*, which can break through the surface of the soil, and a single, deeply thrusting *radicle* (Bradfield 1971:5). These adaptations allow planting at a depth adequate to insure moisture even without additional precipitation, and enable the plant to continue "drawing on this supply of moisture throughout the critical seedling phase, and perhaps through the entire life of the plant" (Bradfield 1971:6).

Hopi corn requires a growing season of 115-130 frost-free days. Late spring frost may kill the young corn plants, forcing another planting in early summer. On the other hand, an early fall frost will prevent the ears from filling out or maturing any further. Corn remaining on the stalk will simply dry on the plant in preparation for picking (Bradfield 1971:6). The Hopi have a growing season of 130 days with 10-13 inches of annual precipitation (Hack 1942:19-20). Adams (1979) presents a convincing argument that previous studies of the Hopi mesas (Gregory 1916; Forde 1931; Page 1940; Hack 1942) underestimated the growing season, thus describing the area as marginal for corn agriculture. The primary reason for this error is failure to consider cold air drainage when interpreting minimum temperature data. Adams (1979:293) reports a growing season of 155-170 frost-free days in the broad valleys, lengthening to 183-193 days on the mesa tops. He estimates that the growing season may be shortened by 10-30 days in areas affected by cold air drainage.

The July and August rainfall is also critical to the production of a good corn crop. Residual soil moisture from snowmelt in the early spring will usually sustain the crops until the end of June. After that, corn depends on summer rains for adequate moisture to sustain growth. Summer rains, even in the vicinity of the modern Hopi villages, are highly variable—0.45 inches to 7.05 inches during July and August over two 10-year periods (Bradfield 1971:6-7).

The Hopi country averages 11-12 inches of precipitation per year, which is not enough to grow corn without using special methods. Floodwater farming benefits from run-off water, in addition to that of rainfall (Hack 1942:21).

Corn harvest usually occurs in late September, after the first frost. After the frost the corn ceases ripening, and may be harvested. Usually corn is allowed to remain on the plant for a week or so to dry prior to being harvested and carried back to the village. Corn was carried to the village "on the cob" in deep baskets or large woven blankets. The Hopi villages are located on mesa tops some 300 to 400 feet above the valley floor, where the agricultural fields were located (Bradfield 1971:21-22).

AGRICULTURAL CONDITIONS AT ISLAND-IN-THE-SKY

Modern data regarding frost-free days and precipitation indicate that Island-in-the-Sky is marginal for agriculture. Frost-free days are ample, averaging 164 days per year with a standard deviation of 15.6 days. This yields a range of 138-193 frost-free days per year, a range ample for agriculture utilizing Hopi-type corn. Precipitation, however, appears to be the controlling factor influencing agriculture in this area. Average annual precipitation equals 9.63 inches (March 1984 through May 1990, Table 3). July and August values vary between averages of 1.70 and .80 inches. Months of highest precipitation include July and October (Table 3).

Most of the areas at Island-in-the-Sky do not exhibit sufficient soil build-up to support agriculture. However, areas delineated as grasslands exhibit the deepest soils (Loope 1977). Sites 42SA8506 and 42SA16858, at the edge of Gray's Pasture, exhibit the only evidence of corn agriculture, with pollen from *Zea mays*, *Cucurbita*, and cf. *Phaseolus*, and macrofloral remains from *Zea mays* and *Phaseolus*. Coincidentally, these areas also have the deepest soils.

Sites 42SA8506 and 42SA16858 are the only two that have evidence of agriculture. Corrected radiocarbon dates between A.D. 750 and A.D. 1050 were derived from 42SA8506, while 42SA16858 yielded a single corrected radiocarbon age of A.D. 800. Standard deviations extend these occupation dates by approximately 150-200 years. Petersen (1987) interpreted paleoenvironmental conditions in the mountains of southwestern Colorado and in the nearby Dolores Project area to be best for agriculture between A.D. 550 and A.D. 1150 or 1200. Summer monsoons in July and August were most intense during this period, and most nearly approximated those of the present. The most favorable time during this entire period for summer monsoons was between A.D. 750 or 800 and 1100. According to corrected radiocarbon dates, this is the time period that 42SA8506 and 42SA16858 were occupied. It is possible that during this period of favorable precipitation, particularly that of summer monsoons, agriculture was possible in the more favorable areas of Island-in-the-Sky.

SUMMARY AND CONCLUSIONS

Pollen and macrofloral analyses at Island-in-the-Sky focused on the identification of available edible vegetal resources and subsistence activities. Pollen and macrofloral samples collected from features and ground stone at ten prehistoric sites were examined. In addition, pollen samples were collected from the present ground surface at five of these sites, and stratigraphic pollen samples were collected at three of these sites. This portion of the study focused on examining the present ground surface record for relationships to modern vegetation communities at Island-in-the-Sky and then using this information to interpret the past environment, as represented in the stratigraphic pollen samples.

Analysis of the present ground surface samples provided information concerning fluctuations in several pollen types, but it was difficult to distinguish between vegetation communities on this basis. The major components of the pollen record are readily wind transported, and were present in varying amounts. These included *Juniperus*, *Pinus*, Cheno-ams, *Artemisia*, Low-spine and High-spine Compositae, and *Ephedra*. Sites associated with grassland vegetation (42SA8503 and 42SA16858) contained moderately high Gramineae pollen frequencies. However, site 42SA8512 displayed a Gramineae pollen frequency as high as that recorded at 42SA8503. A grassland area is noted just to the west of 42SA8503 and probably accounts for wind transport of large quantities of grass pollen onto the site. Site 42SA8503 is the only site located in the *Coleogyne* shrubland. This site exhibited no Rosaceae pollen in the present ground surface samples, even though it was expected, since *Coleogyne is* a member of the Rosaceae family. Sites 42SA415 and 42SA8506 are located in the pinyon/juniper scrubland, but do not exhibit the highest arboreal pollen frequencies. Sites 42SA415 and 42SA8512 exhibit the largest arboreal pollen frequencies in this study. Therefore, modern vegetation association was not particularly well associated with the pollen record. The largest quantities of *Ephedra* pollen were noted at sites 42SA8506 and 42SA16858, which are located close to one another at the Dunes and Gray's Pasture.

Stratigraphic pollen samples indicated that Cheno-am pollen was far more abundant in levels exhibiting cultural association than at present. This may have been due to disturbance across the mesa, which served to encourage weedy plants, such as Cheno-ams. This would have had the added benefit of enriching populations of plants for exploitation by the human population. Gramineae pollen is observed in smaller frequencies in the cultural levels than at the present ground surface. This suggests that grasses may have been less prevalent in the past than they are at present. Alternatively, it is possible that grasses are underrepresented in the past, because their pollen was overshadowed by that of the Cheno-ams, which produce voluminous quantities of pollen, which is readily wind transported. The stratigraphic pollen samples were collected near the edges of sites, where one would expect disturbance during occupation.

The combined pollen and macrofloral records from sites 42SA415, 42SA8500, 42SA8502, 42SA8503, 42SA8512, 42GR913, and 42GR2025 represent prehistoric subsistence economies. The range of plants that appear to have been exploited includes *Fraxinus* (ash as fuel), *Juniperus* (berries and fuel), *Pinus* (seed), Cheno-ams (pollen and seed), *Cleome* (pollen), *Helianthus* (seed), Liguliflorae (pollen), Gramineae (seed and pollen), *Lepidium* (seed), *Opuntia* (pollen), *Physalis* (seed), and unidentifiable berries and seeds (represented by fragments too small to identify). Neither the pollen nor the macrofloral data indicate that grass seeds were the primary resource. Indeed, the modern abundance of Indian ricegrass across the landscape is not reflected in the macrofloral data base. Charred bone fragments were recovered regularly in the flotation samples, indicating that animals were being hunted and processed on a regular basis.

Corn cobs recovered from 42SA8515, a historic corral, are assumed to be modern (cf. Bye 1980:4-5). The presence of modern corn in the vicinity of Gray's Pasture is important in interpreting the prehistoric record, since the possibility for contamination exists. The prehistoric record, however, exhibits corn pollen and charred macrofloral remains in contexts that could not be explained as intrusion from modern sources.

The combined pollen and macrofloral records from sites 42SA8506 (the Dunes) and 42SA16858 (the Gray's Pasture site) are the only ones with evidence of agriculture. Not only do these sites exhibit evidence of agriculture, but this evidence is recovered in abundance and on a consistent basis. Recovery of data on the cultivation of corn, beans, and squash was unexpected at these sites because of the abundance of Indian ricegrass at Gray's Pasture at present and because of the low rainfall on the mesa top. Culturally, however, the presence of cultigens is consistent with other material from Canyonlands National Park (Jennings 1970) and its environs.

The question remains, however, whether agriculture was practiced in the vicinity of Gray's Pasture and the Dunes, or on the floodplains of the Colorado River. The sandstones in Canyonlands are highly permeable and porous, acting as aquifers. Finer-grained rocks, such as shales and mudstones, concentrate this water where they contact the sandstone. Contact springs and seeps may provide surface water in the Park (Loope 1977). The sandy soils of Gray's Pasture promote rapid percolation of rainwater, often wetting the soils to a depth of 50 cm (Loope 1977). This is one of the few areas in Island-in-the-Sky to demonstrate much soil depth. Root systems of grasses are generally shallow and diffuse, allowing them to take advantage of sandy aeolian deposits, such as exist in Gray's Pasture. Modern calculations of average rainfall, however, fall short of that needed to sustain corn agriculture without an additional moisture source. While it has been demonstrated that the period A.D. 750 to 1100 was the most favorable for rainfall, particularly summer precipitation (Petersen 1987), conditions may still have been only marginal at Island-in-the-Sky.

The distribution of evidence for cultigens at two sites near the edge of Gray's Pasture suggests that the deeper aeolian deposits in that area may have been cultivated. If the floodplains of the Colorado or Green Rivers were being utilized for agricultural plots, it is expected that other sites in this area would also have contained evidence of cultigens. Further examination of this matter is recommended. Analysis of soils in Gray's Pasture for corn pollen and phytoliths may shed light on the possible placement of agricultural plots, unless historic records show that corn was used as feed for cattle grazing in that area. If cattle ate corn, including the leaves or stalks, then grazed in the pasture, they would have introduced both corn pollen and phytoliths

to the deposits. If it can be verified that cattle grazing in the pasture were not fed corn, then pollen and phytolith analysis may be of assistance in determining locations of agricultural plots. Analysis of floodplain deposits would be more problematic, as it is possible that all soil present at the time of Anasazi occupation in this area has been removed by more recent floods and deposited downriver. Examination of these soils for pollen and phytoliths should be considered, however.

Zea mays remains were recovered from Features 34 (a human burial), 37 (a charcoal stain), 39 (a large pit), and Vessel DF (Kayenta-affiliated corrugated vessel) at 42SA8506. Pollen was particularly abundant in the soil beneath the vessel, which had a broken bottom. The condition of the *Zea mays* pollen grains indicates that ground corn was being stored in Vessel DF (the pollen grains were torn). The presence of charred *Zea mays* cupules in the burial indicates that corn was buried with this person, possibly as part of a subsistence package. In addition, charred Cheno-am, Gramineae, *Iva*, and *Opuntia* seeds were also recovered, suggesting that they were valued in the economy, and subsequently included in the burial. The presence of *Zea mays* remains (pollen and charred cupules and kernels) in Features 37 and 39 is indicative of processing at the site.

Site 42SA16858 is represented by many more samples than any other site, primarily because of the large quantity of ground stone recovered. Eight metates were washed for their pollen content. In addition, valuable control samples were collected beneath the metates. Occasionally, dirt adhering to the trough of the metate was also sampled for pollen.

Zea mays pollen was recovered beneath all metates, indicating that this processing area had been in use for some time, and that the metates had not always occupied the same spots. This may reflect either long-term occupation or repeated seasonal occupation over several years. Many of the metates yielded *Zea mays* pollen in the wash of the grinding surface, although some did not.

In addition, a relatively consistent pattern of higher Gramineae frequencies was noted in the wash samples, compared to samples collected beneath the metates. This suggests that grass seeds were regularly ground on the metates. Cheno-am frequencies were variable, but generally high. Small aggregates were recovered from almost every wash and beneath all metates. This suggests intensive processing activities involving Cheno-am seeds. *Cleome* pollen was also recovered from washes of vessels, as well as from washes of metate grinding surfaces. This indicates that *Cleome* seeds were also gathered and ground. Large *Ephedra* frequencies were observed in connection with two metates, indicating that *Ephedra* joints were ground or bruised, possibly in preparation for making medicinal tea. Solanaceae and *Shepherdia* pollen were rarely recorded at this site, indicating that these resources may also have been exploited. *Plantago* and *Typha* pollen were recovered almost exclusively in association with metate washes, suggesting that plantain seeds and cattails were ground.

Zea mays remains were recovered from Feature 35, a hearth; Feature 41, a slab-lined cist; Feature 40, a cist containing an olla; from the olla; and from a Mesa Verde Corrugated vessel at 42SA16858. Recovery of *Zea mays* remains in these locations indicates both processing and storage activities. In addition, the olla and the cist containing the olla yielded evidence of *Cucurbita* pollen, which may represent the cultigen squash, and both *Phaseolus* pollen and a charred Phaseolus bean. This olla provided the only evidence of other cultigens, squash and beans, at this site. These remains are rarely recovered, and their recovery in this context is extremely fortuitous.

Collected or gathered foods represented in the pollen and macrofloral records from 42SA8506 and 42SA16858 include: *Celtis* (pollen), *Pinus* (seed), Cheno-ams (seed, pollen), *Chenopodium* (seed), *Cleome* (pollen), *Iva* (seed), Liguliflorae (pollen), Liliaceae (pollen), *Opuntia* (pollen and seed), *Plantago* (pollen and seed), *Shepherdia* (pollen), Solanaceae (pollen), *Typha* (pollen), and unidentifiable seeds and berries (fragments too small to identify).

The diversity of resources represented indicates exploitation of all vegetation communities on the mesa, as well as along the floodplains. The presence of *Typha* pollen only in association with metate washes suggests that cattails were ground at 42SA16858.

Pollen and macrofloral analyses at sites 42SA8506 and 42SA16858 suggest that agriculture was, indeed, possible in the vicinity of these sites. Identification of the location of the agricultural fields was not possible through these analyses, as no probable field locations were sampled. Examination of climatic data suggests that agriculture would have been a marginal undertaking on the mesa, if conditions were similar to present during the Anasazi occupation. Previous work by Petersen (1987) in the Dolores Project area notes that the peak in summer storms for that area occurred between AD 550 and 1100. It is possible that Island-in-the-Sky was also the recipient of increased summer storms during the same period, thus increasing the potential for agriculture in marginal areas. The floodplain of the nearby Colorado River and the grasslands of Gray's Pasture should not be overlooked as likely areas for agricultural field locations. It may be possible to address agricultural field location through pollen and phytolith analysis, if appropriate sediments can be identified in the floodplain and if modern contamination by cattle with a diet including corn can be ruled out at Gray's Pasture.

ANALYSIS OF CHARRED WOOD REMAINS

INTRODUCTION

In 1983, 1984, and 1985 archeological fieldwork was conducted under the joint auspices of the National Park Service and the University of Nebraska-Lincoln at a series of sites located in Canyonlands National Park, Utah. Charcoal samples were collected from seven of these sites and submitted to the author for analysis. The goals of the analysis were to identify those woods used by the prehistoric inhabitants and to describe the broad environmental setting suggested by those identifications.

The charcoal samples consisted of field collections gathered when an excavator observed concentrations of charred wood. Such manual, non-random collection favors large obvious specimens. Due to variables of charcoal production, deposition, preservation, and recovery, as well as to species-specific qualities of the woods used, this method normally results in an inaccurate picture of those woods used prehistorically. Instead, accurate lifeway and vegetational reconstruction based on charcoal depends upon randomly collected specimens gathered within a consistent sampling scheme. Our subsampling of float-recovered charcoal across a range of size-grades helps insure that species are neither overlooked nor overemphasized due to the unique circumstances surrounding each ancient fire (Zalucha 1982).

Since none of the specimens were recovered from processed matrix samples, it would be inappropriate to use them as the basis for a comprehensive plant use or vegetational reconstruction. However, this does not mean that the Canyonlands charcoal is without value. In terms of lifeways, each identification indicates a selected tree or shrub. We must simply bear in mind that other woody plants may also have been used for which no evidence was recovered. A wood common in the analysis may actually have been a second or third choice.

The question of environment must be addressed in conjunction with an examination of the pollen record for the area. The taxa identified can be compared with those to be expected, given the pollen data. Consistencies would support the accepted palynological view, while the common presence of anomalous taxa would suggest different vegetational/climatic conditions. Any anomalous taxa would at most indicate areas for further research, however, since the non-random collection method may have obscured differential cultural selection; very uncommon trees may have been highly valued and selected out of proportion to their natural importance.

METHODS

Upon receipt of the charcoal, each sample was size-graded into fractions >3.35mm and <3.35mm. All specimens in the larger fraction were examined and identified if possible. Although charcoal fragments as small as 1.0 mm in diameter can often be identified, because of the collection method employed specimens from the smaller fraction were not examined. It is very unlikely that an excavator would note and collect isolated specimens smaller than 3.35 mm. Such specimens in this study are much more likely to represent fragments broken off the larger pieces in a sample.

The charcoal was identified using a binocular incident light microscope with a maximum magnification of 1200X. The specimens consisted mostly of the wood of conifers. Since many western coniferous species are not included in wood keys, initial examinations were made using structural criteria sufficient to arrive at generic level identifications. Next a range of possible species was examined, given the park's elevation and likely vegetational history of the area based on pollen. Species level determinations were made by reference to modern specimens on file in the author's comparative collection and to those in the Herbarium of the University of Wisconsin-Madison.

THE SITES AND THEIR MODERN VEGETATION

The sampled sites are situated throughout the mesa. The southern extension of the Island is represented by a single site, 42SA8500, which is on Murphy

Point where it branches to the west from Grand View Point. Two sites lie on the northwestern portion of the Island, 42SA415 on Willow Flat, and 42SA8512 near the Upheaval Dome. To the northeast, four sites were sampled. 42SA8506 and 16858 are located in the southern portion of Gray's Pasture; 42SA8502 is in the northern end of the Pasture; and lying outside the park on the western side of Big Flat is 42GR2025 (see Figures 28 and 31, pages 90 and 98).

Loope (1977) recognized five major environmental zones within Canyonlands National Park, each with its distinctive vegetational pattern (see previous discussions). Two vegetational types are of interest here in light of the site locations: grasslands and pinyon-juniper (*Pinus edulis-Juniperus osteosperma*) woodlands.

Most of the sites are in grasslands. 42SA8500, by contrast, is in an area of patchy pinyon-juniper woodland. The sites generally appear to have been short-term, special-use sites. None of the sites appear to have had immediate access to water. Although some are relatively close horizontally to springs, seeps, or intermittent water courses, the vertical distance is up to several hundred feet. An exception is 42SA415, which is relatively close both horizontally and vertically to Willow Seep.

The grasslands of the Island-in-the-Sky occur at an average elevation of 1,826 m (6,000 ft) on deep (>50 cm), relatively xeric, sandy aeolian soils with an average slope of 15 degrees (Loope 1977). They are dominated by needle and thread (*Stipa comata*), galleta (*Hilaria jamesii*), Indian ricegrass (*Oryzopsis hymenoides*), and blue grama (*Bouteloua gracilis*). A wide variety of forbs also occur, although usually in low densities. Woody plants are quite uncommon, restricted to shrubs such as winterfat (*Certoides lanata*), rosemary mint (*Poliomintha incana*) and, in Gray's Pasture, joint fir (*Ephedra viridis*) (Loope 1977:48). Loope (1977:61-62) explains the low frequency of shrubs and virtual absence of trees as a function of their root systems, which cannot efficiently absorb the infrequent moisture as it rapidly percolates through the coarse soil. By contrast, the grasses, with their diffuse root systems forming a mat near the surface, absorb the maximum amount of moisture.

Pinyon-juniper woodlands in Canyonlands occur at varying elevations in areas with exposed, jointed bedrock. This seemingly xeric landscape is actually one of the wettest vegetational zones in the park, since the fissures in the rock collect moisture on which the trees survive. The sides of washes also often support typical pinyon-juniper species. Associated with them at a high rate of constancy are at least 26 species of shrubs, whose frequencies within stands, however, tend to be low. An especially common associate on Grand View Point is blackbrush (*Coleogyne ramosissima*), the dominant plant on benches with this (<30cm) regolith. Two other trees occasionally occur, singleleaf ash (*Fraxinus anomala*) and Gambel oak (*Quercus gambelii*). The former is seen most often on canyon slopes, as well as in sheltered portions of broken slopes of the lower Cutler Formation below the White Rim. The oak, by contrast, is more typical of lower elevation alluvial benches. Occasional specimens occur on canyon walls (Loope 1977).

PALYNOLOGY

The Holocene vegetational history of the western United States is extremely complex. Our understanding of these complexities is limited by the relatively small number of pollen samples available for study. At the time of this analysis, no pollen studies dealt with the immediate area of Canyonlands National Park. We must therefore interpolate, using data from neighboring regions and sometimes including material from different elevations.

The sparse pollen data for middle elevation regions of southern Nevada suggest that essentially modern conditions became established there during the early Holocene. Van Devender and Spaulding (1979) observed modern-like desert scrublands at the same elevation as that of the study area by 7,500 B.P. At slightly higher elevations they observed the modern pattern of pinyon-juniper woodlands 2,000 years earlier. Although similar to those in Canyonlands structurally, the Nevada trees are *Pinus monophylla*, not *P. edulis* as in Utah.

At Hogup Cave in northwestern Utah, pollen and plant macrofossils suggest the presence of essentially modern vegetation by about 8,500 B.P., although this area contrasts with Canyonlands in terms of elevation and vegetation structure (Harper and Alder 1970). At Chaco Canyon in northwestern New Mexico, there is conflicting evidence about the importance of juniper (*Juniperus monosperma*) and *Pinus edulis* during the last 6,000 years (Betancourt and Van Devender 1981; Hall

1977, 1981). Although woodlands may not have existed, at least scattered individuals of both were probably present.

At higher elevations to the east of the study area the vegetational history is much more complex, showing sharp and often contrasting differences from site to site through time (Baker 1983). Although the relatively close Alkali Creek Basin in west-central Colorado is at a different elevation than the study area and possesses a different vegetation type, it is interesting that Markgraf and Scott (1981) saw the establishment of modern conditions by 5,000 B.P.

In summary, although the data are sparse, palynological studies suggest the emergence of essentially modern conditions within the desert Southwest relatively early in the Holocene. Our current knowledge indicates that climatic and vegetational conditions within Canyonlands National Park have been similar to those of today at least during the period covered by the charcoal samples, the oldest of which may date from as early as 3,000 B.P.

RESULTS

The charcoal identifications from the seven sampled sites are shown in Table 75. Examination of this table leads to five conclusions: (1) the prehistoric environmental setting was similar to that of that of today, (2) juniper wood overwhelmingly dominates the overall assemblage, (3) each site assemblage tends to be dominated by a single wood, (4) pinyon pine occurs very late in the sequence, and (5) minor associates of the pinyon-juniper community were utilized in addition to the dominant trees.

The obvious dominance of *Juniperus osteosperma* at six of the seven sites, together with the strong presence of *Pinus edulis* at the seventh, is clearly suggestive of the jointed bedrock woodlands which are the only modern significant sources of wood at the site elevations. This finding is consistent with the palynological data indicating stable vegetational patterns at this elevation in southeastern Utah over the last few millennia. Although it is true that the non-random sampling mode may have obscured anomalous taxa, there is no reason to suspect this on an *a priori* basis. If anomalous taxa had beem present vegetationally in significant numbers, one could reasonably expect at least one of the sites, by chance, to give some indication of their presence, even given non-random sampling. This result does not, in itself, form the basis for a vegetational or environmental setting similar to the modern pattern throughout the use span of the sites.

It is important to stress that the relative proportions of archeological juniper and pinyon pine can in no way be related to the cultural wood preferences of the prehistoric inhabitants. The large number of juniper specimens frequently seen in a single sample may reflect the fragmentation of a single log, not the use of many logs. Pinyon pine may have been heavily used at sites where it was not identified, since ancient fire conditions and sampling methodology may have caused it to be underrepresented or overlooked. Thus to claim that juniper and pine were used in a 9:1 ratio over time would be a gross misunderstanding of the findings. Following the same line of reasoning, the numerical dominance of juniper does not necessarily imply anything about the proportional makeup of the prehistoric woodlands. This is especially true, since any claim of correspondence between the charcoal distribution and woodland make up would involve an unsubstantiated assumption of random prehistoric wood collection.

At most, the trends of juniper and single taxon dominance seen in the charcoal form the basis for hypotheses about cultural wood preferences and woodland structure. Such hypotheses can be tested only through the size-grade analysis of specimens randomly collected in bulk matrix samples.

If in fact no pine was used at the juniper-dominated sites, the apparent shift to pinyon at 42SA8502 may indicate changing wood use preferences through time. Further sampling is required to confirm or deny this hypothesis. Alternately, the pine dominance there may simply reflect chance local availability.

The presence of *Fraxinus* spp. at 42SA8512, and diffuse-porous woods there and at SA8502, indicates that the dominants of the pinyon-juniper woodlands were not the only woods exploited. Species of *Fraxinus* cannot be identified on the basis of wood structure. However, given the especially reasonable assumption of vegetational continuity at this late site, the charcoal surely represents *F. anomala*. The diffuse-porous charcoals suggest the use of one of the many shrubby species of the pinyon-juniper understory.

Table 75. Charcoal identification counts by site, date, and provenience.

Site, Date	Provenience	Taxon	Count
42GR2025			
AD 900 - 1205	CANY-5 FS, 0-10 cm	*Juniperus osteosperma*	19
42SA415			
410 BC - AD 15	CANY-16 F50, N1/2	*Juniperus osteosperma*	10
no dates	CANY-17 F50, S1/2	*Juniperus osteosperma*	43
42SA8500			
BC 1095 - AD 790	CANY-15 F47, NE1/4	*Juniperus osteosperma*	8
AD 65 - 430	CANY-14 F46, SW1/4	*Juniperus osteosperma*	38
AD 1425 - 1660	CANY-13 F45, N1/2	*Juniperus osteosperma*	29
42SA8502			
AD 1235 - 1415	CANY-1 F7, W1/2	*Pinus edulis*	1
AD 1425 - 1655	CANY-2 F6, W1/2	*Pinus edulis*	7
AD 1425 - 1655	CANY-3 F26, S1/2	*Pinus edulis*	10
AD 1485 - 1795	CANY-4 F15, NE1/4	*Pinus edulis* Semi-diffuse porous	10 2
42SA8506			
AD 585 - 900	CANY-19 F36, SW1/4	*Juniperus osteosperma* cf. *Prunus* spp.	45 2
AD 620 - 895	CANY-20 F34	*Juniperus osteosperma*	6
AD 875 - 1055	CANY-11 F39, W	*Juniperus osteosperma*	13
AD 895 - 1195	CANY-6 F33, SE1/4	*Juniperus osteosperma*	1
AD 895 - 1195	CANY-9 F33	*Juniperus osteosperma*	1

Table 75. Concluded.

Site, Date	Provenience	Taxon	Count
42SA8506, continued.			
AD 895 - 1195	CANY-10 F33	*Juniperus osteosperma*	1
AD 920 - 1230	CANY-12 F38, post?	*Juniperus osteosperma*	1
42SA8512			
AD 1345 - 1650	CANY-18 F56, W1/2	*Fraxinus* spp. *Juniperus osteosperma* Diffuse-porous	2 42 2
42SA16858			
AD 610 - 1020	CANY-7 F35, S1/2	*Juniperus osteosperma*	14
no dates	CANY-8 37-40 cm	*Juniperus osteosperma*	12

The original use of the charred wood is not clear. Undoubtedly much of it reflects firewood, but tool handles, ephemeral structures, or, at 42SA8506, even a house may be represented. The wood of *Pinus edulis*, though heavy, is soft. That of *Juniperus osteosperma* is hard and more durable than that of pinyon (Elias 1980:47,144). Singleleaf ash wood is also heavy and hard (Preston 1976:345). Given these minimal structural differences and the location of most of the sites in grasslands to which wood would have had to have been carried, the use of the nearest convenient dead wood is suggested. Considering the general scarcity of wood in the immediate area, task-specific cultural preferences may have been minimal.

Site 42SA8506 produced two possible specimens of *Prunus* spp. cherry. This wood is difficult to explain. Loope (1977:107) noted the occasional presence of *Prunus virginiana*, choke cherry, in "hanging gardens," small protected areas with constant moisture. These areas support mesic vegetation very different from that seen in the vast majority of the park. However, 42SA8506 is located far from any source of permanent moisture. Even if one were near, it is hard to imagine firewood exploitation of such an isolated, often difficult to reach, place, although exotic woods might be favored for special uses such as tool handles. The two specimens are insufficient grounds upon which to posit vegetational change, especially considering their uncertain identification. The most likely explanation is the misidentification of some minor shrubby species whose wood structure resembles that of *Prunus*.

In conclusion, this study suggests an environmental setting quite similar to modern conditions throughout the time span of the sampled sites. The prehistoric inhabitants made use of the only woods conveniently available to them at the mesa elevation. Information about fuel preferences and the specific proportional makeup of the ancient woodlands could not be determined, based on the available evidence.

TAPHONOMIC ANALYSIS OF FAUNAL REMAINS

INTRODUCTION

The purpose of this investigation was to examine the taphonomic character of the unidentifiable bone fragment component of the bone assemblages recovered from the study area. Unidentifiable bone fragment is, for the purposes of this analysis, defined as a fragment that can not be identified to the anatomical element from which it originally came, e.g., humerus, femur, vertebrae. However, other fragments, such as those from teeth, long bones, and bones which could be identified to the element, but do not add to the MNI calculation have also been included. While unidentifiable fragments were the main focus of this study, the identifiable bone was also analyzed for the same attributes and necessarily included into the overall analysis and pattern recognition study.

Osteoarcheological analysis has long ignored the possibility of using unidentifiable fragments in faunal analysis, other than as gross indicators of some posited prehistoric behaviors, e.g., marrow and grease processing, trampling, or waste disposal activities. It would be safe to say that the analysis of many bone assemblages is based upon only those bones that can be identified with certainty as to element and can be used in MNI calculations. In fact it has been stated explicitly that,

> ... it is rare that nonidentifiable bones provide any information that is not also available from the identifiable ones. Consequently, the nonidentifiable bones are frequently sorted out at a very early stage in the analysis and ignored thereafter (Klein and Cruz-Uribe 1984:17).

We disagree with this sentiment and find it rather appalling, particularly since the determination of the worth of unidentifiable fragments, as related to the rest of the osteological assemblage, *a priori*, eliminates that particular component from any analysis or questioning of the formation processes of any given faunal assemblage. The previous quote also assumes that all behavioral and taphonomic agents of assemblage formation act equally upon identifiable and unidentifiable bones. This is demonstrably not the case. The example of ignoring bone fragments can be likened to aspects of early stone tool analysis in which the debitage or waste of stone tool manufacture was ignored, because it was, after all, the finished tool that expressed the maker's, ideas, ideals, mental templates, or cultural/ethnic identity. In hindsight, it is obvious that those attitudes were fundamentally nonscientific and woefully misguided. Debitage analysis has become a major and necessary focus of most chipped stone tool analysis. Much the same can be said about osteological assemblage analysis, particularly with the recognition that non-human taphonomic and geomorphological factors play significant roles in the development of archeological sites and in the dimensional patterning expressed in the assemblages recovered from sites. The purpose of the present analysis is to provide some understanding of the patterning revealed in the bone fragment component of the sites discussed, in relation to possible causal agents, be they human or non-human.

CLASSIFICATION OF BONE FRAGMENTS

Table 76a presents a tabulation of the variables of the bone fragment component from the faunal assemblages of sites excavated in Canyonlands National Park. The anatomical element classes are defined as follows. Unidentifiable bone fragments (UN) are those fragments that cannot be reliably identified to the anatomical element from which they came. Generally, these fragments range from >0 - 5 cm, measured on the long axis or diameter of the fragment. However, due to constraints beyond the control of the investigators measurements were not taken on the fragments. The lack of measurements puts limitations on a detailed taphonomic analysis in the dimension of looking at the size of fragments (as sedimentary matrix particles) and their behavior and representation in the different strata of the archeological sites. But, a satisfactory, if partial, analysis can be conducted without this information.

Table 76a. Summary of tooth and bone fragments in faunal assemblages from sites in Canyonlands National Park, Utah (element count and row percent; total counts and column/row percent).

Site	Element						Total
	UN	TH	LB	FB	CB	Other	
42GR913	-	-	-	-	-	-	0
42SA415	2 (40.00)	2 (40.00)	-	1 (20.00)	-	-	5 (0.08)
42SA8502	2833 (84.32)	322 (9.58)	161 (4.79)	6 (0.18)	4 (0.12)	34 (1.01)	3360 (57.6)
42SA8503	267 (100.00)	-	-	-	-	-	267 (4.6)
42SA8506	1138 (89.74)	107 (8.44)	20 (1.58)	-	-	3 (0.24)	1268 (21.7)
42SA8509	29 (90.63)	3 (9.37)	-	-	-	-	32 (0.55)
42SA8512	758 (92.44)	49 (5.98)	6 (0.73)	-	-	7 (0.85)	820 (14.1)
42SA16858	74 (94.87)	-	-	-	-	4 (5.13	78 (1.3)
Total	5101 (87.5)	483 (8.3)	187 (3.2)	7 (0.12)	4 (0.07)	48 (0.82)	5830 (100)

UN = Unidentifiable bone fragments.
TH = Tooth enamel and tooth fragments.
LB = Long bone flakes and fragments.
FB = Flat bone fragments.
CB = Cancellous bone fragments.
Other = See Text.

Tooth fragments (TH) represent broken tooth enamel, tooth interiors, and roots that cannot be identified to the specific tooth, e.g., molars, incisors. Inspite of the generic level of identification, these fragments are useful in that they indicate the past presence of skull and/or mandibular elements at the sites. Tooth fragments do not weather the same as bone fragments and are not given weathering stage classifications.

Long bone fragments (LB) are, because of the bone structure, obviously derived from limb bones. They, however, cannot be identified to specific anatomical element. More specifically, long bone fragments in this analysis were restricted to bones that evidenced green bone fracture. It may appear that such fragments were most probably produced by humans during the course of butchering and consumption. However, it is recognized that such fragments may also be produced by other means.

Flat bone fragments (FB) are, because of cortical and interior structure and appearance, presumed to

have come from such elements as skulls, scapulae, or innominates, but cannot be positively identified as such. Cancellous bone (CB), is bone derived predominantly from the interior portions of long bone articular ends, but can also come from other elements, e.g., vertebrae, innominates. The exterior or cortical surface is usually absent on cancellous bone fragments. Large frequencies of cancellous fragments have often been presumed to be indicative of bone grease processing. Whether this can be demonstrated for any given assemblage remains problematic; however, substantial portions of cancellous fragments do, undoubtedly, indicate severe mechanical/chemical bone attrition. The class designated "Other" in Table 76a refers to bone fragments which could be identified to an anatomical element, but did not affect the MNI calculations of the identifiable bone component.

Bone fragments were examined individually and observations were recorded for each fragment. Fragments which obviously had been broken during and after excavation were largely discounted from the summation of the total, unless they could be refitted, or it was evident that they had only suffered edge damage. In this way, inflation of fragment counts, due to "bag breakage," was kept at a minimum.

BONE WEATHERING

Bone weathering has concerned archeologists for many years; however, the weathering process and the mechanical/chemical interaction between bone and various weathering agents is still poorly understood. In the large sense, the greater the degree of weathering evident on a bone, the longer it has been exposed to ground surface conditions. Unfortunately, bone does not weather at constant and equal rates due to a number of micro-environmental factors, and unless a faunal assemblage is buried within a year or two of its creation, differential weathering, even on the same bone, begins to take place. However, and as will be discussed in depth later, bone weathering stages can be used to construct stratigraphic profiles of bone fragments and inform on the depositional history of the site. Generally, the differential proportions of the different weathering stage classes does inform on the relative length of exposure and/or the degree of mixing or disturbance the assemblage has endured.

The rationale for using bone weathering as an indicator of occupational surface stability, length of exposure, and site matrix disturbance is detailed in the following examples. If, for instance, a bone assemblage evidences a predominance of one weathering stage over another, say Stage 1, it is reasoned that the deposition of sediments at the site was relatively rapid and the bone was not exposed for any great length of time. The drying out, or degreasing, of fresh bone usually takes place within a year and oftentimes sooner, given the intensity of temperature and humidity variation. Conversely, a bone assemblage with a very high proportion of Stage 4 weathering would indicate long term exposure on a stable surface.

The weathering stage categories employed in this analysis generally follow that presented by Behrensmeyer (1978) with some modification. Those modifications have resulted in a somewhat finer resolution of determination for the different weathering stages (Todd 1983). The definitive characteristics are as follows:

Stage 0 - The bone is unweathered and greasy.

Stage 1 - The bone surface is intact, dry, and free of cracks in the cortex.

Stage 2 - The bone surface begins to show minute surface deterioration, with some longitudinal cracking.

Stage 3 - The bone surfaces exhibit light surface flaking with cracks being more numerous and deeper.

Stage 4 - Surface bone shows moderate flaking, with extensive cracking and small patches of underlying fibrous bone apparent.

Stage 5 - Bone surface highly deteriorated to the point of large areas of fibrous bone being exposed, cracking goes completely through the cortex, and the structural integrity of the bone is weak.

Stage 6 - Bone literally falling apart and chalky.

In this analysis only Stages 1 - 5 were used, plus the indeterminate Class 7, which indicates the fragment could not be assigned to a definite weathering stage. Class 7 was generally composed of tooth fragments, cancellous bone, highly calcined bone, and fragments simply too small to classify reliably.

OTHER CLASSIFICATIONS

Tables 76b and 77 also summarize the presence and absence of burning, non-human gnawing and possible gnawing, and cutmarks and possible cutmarks for the total bone assemblage and for the identifiable bones, respectively. The purpose of including these categories was to provide more information on the nature of bone modification and attrition that took place in the past. Although not listed in the tables, root etching was also evaluated during the analysis, but was found not to have had a significant role in the modification of the assemblages discussed here.

LIMITATIONS OF THIS ANALYSIS

The analysis presented here by no means contains the full range of investigation techniques that can be brought to bear on a bone assemblage. Spatial analysis has been limited to the vertical dimension. A three dimensional analysis of each site would have been the ideal situation, but given time and funding constraints, this was not possible. Furthermore, the excavations at these sites were not intended to open large contiguous areas that are necessary for in-depth spatial analysis. Therefore it was not possible to know the degree of stratigraphic correlation between excavated units.

Table 76b. Summary of bone fragment condition for faunal assemblages from sites in Canyonlands National Park, Utah (specimen count and row percent; total counts and column/row percent).

Site	Condition					Total
	BU	GN	PG	CT	PC	
42GR913	-	-	-	-	-	-
42SA415	-	-	-	-	-	5 (0.08)
42SA8502	1224 (36.43)	1	2	4	9	3360 (57.6)
42SA8503	256 (95.88)	-	-	-	-	267 (4.6)
42SA8506	699 (55.13)	-	-	-	-	1268 (21.7)
42SA8509	29 (90.63)	-	-	-	-	32 (0.55)
42SA8512	292 (35.61)	-	-	-	-	820 (14.1)
42SA16858	24 (30.77)	-	-	-	-	78 (1.33)
Total	2524 (43.3)	1	2	4	9	5830 (100)

BU = Burned bone.
GN = Gnawed bone.
PG = Possibly gnawed bone.
CT = Cutmarks.
PC = Possible cutmarks.

Table 77. Summary attributes of the identifiable bone components from assemblages from sites in Canyonlands National Park, Utah.

Site	Condition					Total
	BU	GN	PG	CT	PC	
42SA415	-	-	-	-	-	-
42GR913	-	-	5 (5.05)	2 (2.02)	-	99 (12.7)
42SA8502	137 (46.65	14 (4.56)	49 (15.96)	13 (4.23)	4 (1.30)	307 (39.5)
42SA8503	23 (82.14)	-	1 (3.57)	1 (3.57)	-	28 (3.6)
42SA8506	3 (21.43)	-	2 (14.29)	-	-	14 (1.8)
42SA8509	-	-	-	-	-	-
42SA8512	25 (8.80)	1 (0.35)	20 (7.04)	5 (1.76)	-	284 (36.5)
42sa16858	2 (4.35)	-	-	-	-	46 (5.9)
Total	190 (24.4)	15 (1.9)	77 (9.9)	21 (2.7)	4 (0.51)	778 (100)

BU = Burned bone.
GN = Gnawed bone.
PG = Possibly gnawed bone.
CT = Cutmarks.
PC = Possible cutmarks.

A second limitation is the lack of control over the amount and degree of bioturbation that has affected the sites. This condition however, is not due to any shortsightedness by the investigators, but rather to the lack of any substantive techniques or methods with which archeologists in general could deal with this problem. This problem requires actualistic and experimental research, which, at this time, has not been conducted in any great depth, to provide controls and measures for determination of vertical and horizontal displacement by various biological factors, e.g., roots, burrowing rodents, and insects.

A final consideration is the absence of sediment particle size analysis and bone fragment size analysis. Again, given the limitations of time and money, these types of observations simply could not be generated.

However, we have presented a useful way of looking at certain dimensions of site formation processes that can be utilized in developing inferences about site use and re-use and the types and intensities of activities carried on at the sites.

ANALYSIS OF THE BONE ASSEMBLAGES

The frequencies and percentages given in the tables for the following sites were derived in the following manner. First, the subset of classifiable weathered bone frequencies was segregated from the total of assemblage frequencies and percentages of each weathering class were calculated from only the total of the weathered bone subset. This was done in order to provide proportions that could be readily used in the development of the stratigraphic weathering profiles. In other words, the total number of bones per arbitrary excavation level was not used at this point in the pattern recognition study. The Class 7 or non-assignable bones do not contribute to proportions listed for the bones assigned to the weathering stage classes.

Second, the frequency/percentage profiles were generated from the total number of bones represented in each arbitrary level and do indicate that proportional contribution to the overall assemblage total. Both of these manipulations were calculated to demonstrate patterning within the weathering stage classes and the proportionate representation of all bones at a given excavation level.

42GR913

No weathering table is presented for this site since nearly the entire assemblage exhibited Stage 1 weathering. All of the 99 bones from this site were identifiable. 42GR913 was, relative to the other sites, quite deep, with the major levels of bone deposition found from 65 cm bs to 105 cm bs. The lack of any weathering beyond Stage 1 would indicate rapid burial of the bones, and Level 14 is not believed to be a deflational surface.

42SA415

As can be seen from Table 76a, the fragment component from this site is virtually non-existent, and little can be said taphonomically.

42SA8502

This assemblage (Table 78) was the largest recovered from the sites discussed here and is taphonomically the most intricate. Patterning suggests that there were at least two distinct occupational events that have been somewhat smeared by sediment aggradation and deflation. Profiles indicate that the first occupation occurred between 40 cm bs to 60 cm bs, and the second occupation involved levels 0 - 15 cm bs. The intervening levels are problematic. Do they represent a continuing, but less intense, use of the site by humans, or do they evidence mechanical deposition by non-human factors such as vertical movement of the bones, both up and down, from the two occupation levels, or do these levels represent a "feeding" of new bones from an upslope source? These questions will be examined further on in this discussion. Table 76a shows that unidentifiable fragments are the overwhelming proportion of the assemblage, with tooth fragments also well represented. The long bone flake category, however, is somewhat ambiguous when only the percentage proportion is considered. With a frequency of 161 long bone flake specimens it is suggested that the processing of long bones for marrow was an important activity at the site. No positively identifiable impact cones were observed on the long bone flakes; however, on bone of this size (presuming deer/mountain sheep size limb bones) the lack of impact cones is not uncommon. Depending on the location of impact, or other forms of breakage, the fracture stress lines may diverge then converge at points well away from the impact, producing a long bone flake with no percussion cone. Almost all of the long bone flakes appeared to have been derived from deer/mountain sheep sized animals. Given the number of hearth features at this site, it appears that activity there was relatively intense and the period of occupation prolonged, although it does not appear to be a long-term residential site.

Four positive cutmarks and nine possible cutmarks were observed on bone fragments. Burned bone made up a substantial portion of the assemblage, which is not surprising, given the number of hearths uncovered at the site. Carnivore gnawing was absolutely identifiable from one specimen and possible for two others. Whether this gnawing represents camp dogs or post-occupation scavengers is indeterminate.

In Table 78 it is evident that, by arbitrary stratigraphic level, there is not an even or proportional distribution of weathering stages. To facilitate the comparison of the weathering stages between and within the stratigraphic levels the bone fragments which could be assigned to a weathering stage have been segregated into subsegments of the overall assemblage. Percentages are derived from the subtotal of those assignable fragments. Since the bone used in this analysis was

Table 78. Summary of weathering stages in relation to the depth from site 42SA8502 (count and row percent; total count and column/row percent).

Level and Depth (cm)			Weathering Stage 1	2	3	4	5	Sub-total	7*	Total
1	≥ 0	<5	5 (12.20)	9 (21.95)	8 (19.51)	17 (41.46)	2 (4.88)	41	478	519 (15.45)
2	≥ 5	<10	19 (20.21)	40 (42.55)	24 (25.53)	9 (9.57)	2 (2.13)	94	891	985 (29.32)
3	≥10	<15	6 (20.70)	13 (44.83)	6 (20.70)	3 (10.35)	1 (3.45)	29	125	154 (4.58)
4	≥15	<20	14 (31.82)	12 (27.27)	14 (31.82)	4 (9.09)	-	44	55	99 (2.95)
5	≥20	<25	3 (6.52)	15 (32.61)	16 (34.78)	12 (26.09)	-	46	43	89 (2.65)
6	≥25	<30	15 (20.55)	14 (19.19)	3 (4.11)	39 (53.42)	2 (2.74)	73	150	223 (6.65)
7	≥30	<35	4 (4.76)	21 (25.00)	47 (55.95)	11 (13.10)	1 (1.19)	84	127	211 (6.28)
8	≥35	<40	8 (11.88)	19 (20.00)	49 (51.88)	10 (10.53)	9 (9.47)	95	89	184 (5.48)
9	≥40	<45	27 (16.77)	34 (21.12)	39 (24.22)	49 (30.43)	12 (7.45)	161	109	270 (8.04)
10	≥45	<50	34 (14.98)	72 (31.72)	73 (32.16)	33 (14.54)	15 (6.61)	227	269	496 (14.76)
11	≥50	<55	9 (16.98)	29 (54.72)	13 (24.53)	2 (3.77)	-	53	228	281 (8.36)
12	≥55	<60	3 (21.43)	7 (50.00)	1 (7.14)	3 (21.43)	-	14	130	144 (4.29)
13	≥60		1 (100.00)	-	-	-	-	1	11	12 (0.36)
Total			148 (4.4)	285 (8.5)	293 (8.7)	192 (5.7)	44 (1.3)	[962] (20.6)	2705 (80.3)	3667 (100)

* non-assignable fragments, inderterminate Class 7

recovered from arbitrary levels, the correspondence between episodes of deposition and weathering and natural strata is somewhat blurred. Levels 1 through 3 indicate a relatively high level of mixing of the weathering stages. This would indicate a low degree of surface stability either by deflation or other mechanical mixing. It could also indicate a rather steady rate of bone deposition. This implies that fresh bone was added to the levels at an equable rate corresponding to the weathering and burial of any previous bones.

However, Stage 4 dominates in Level 1, while Stage 2 dominates in Levels 2 and 3. A plausible interpretation is that Level 1 is a deflational surface, while Levels 2 and 3 represent an occupational surface(s), because of the rapid burial implied by the high percentages of Stage 2 weathering and the absolutely greater frequency of bones and fragments in these levels. Levels 4 and 5 also evidence heavy mixing of weathering stages, with no dominance of any one weathering stage. The absolute number of bones also declines for these two levels. Level 6 shows a dramatic increase in Stage 4 weathering, indicating some long-term stability; however, Stages 1 and 2 are also well represented, while Stage 3 is quite small in proportion. Levels 7 and 8 show a dominance of Stage 3, with substantial proportions of Stage 2, again indicating relative stability on an aggrading surface.

Levels 9 and 10 exhibit fairly proportionate mixing of weathering stages, perhaps also indicating another deflational episode. Levels 11 and 12, however, demonstrate an overwhelming dominance of Stage 2 weathering, showing a rapid burial; however, weathering Stages 3 and 4 are well represented in Levels 11 and 12, respectively, implying that there has been some mixing of the bones. Level 13 is, of course, barely represented.

While it is apparent that bone was more or less being constantly deposited upon the strata, the rate of deposition varied through time, as did the rates of aggradation and deflation. Levels 1 through 3 and 9 through 12 appear to have been major occupational episodes; however, it is also evident that deflation has played a role in the composition of the weathering stage classes in these levels. Levels 4 through 8 are somewhat problematical in that these appear generally to be aggrading surfaces; however, Levels 5 and 7 do show evidence of a minor deflational event.

42SA8503

As Table 76a demonstrates, the fragment component of this small assemblage was composed entirely of unidentifiable bone. Both the unidentifiable and identifiable bones were heavily burned. A possible gnawed bone and one cutmark were observed. The major portion of the bones was recovered from 0 - 10 cm bs, although some bone was recorded down to 30 cm bs.

Of the fragment component only 6 bones were assignable to weathering Stage 1. There were 12 identifiable bones exhibiting Stage 2 weathering, and one bone each for Stages 3 and 4. The remainder were unassignable to a weathering stage. In spite of the paucity of evidence, it appears that this site was buried quickly, given the predominance of Stage 1 and 2 weathering.

42SA8506

Table 76a shows the dominance of unidentifiable fragments in this component of the bone assemblage. Tooth fragments were well represented, and 20 long bone fragments were observed. A little over half of the fragments evidenced burning; however, there was no evidence for the other forms of cultural and natural bone modification.

However, as the figures in Table 79 attest, the limits of statistical significance are being approached and the information that weathering stages and bone frequencies provide must be used cautiously. For example, Table 79 reveals that only seven bones or fragments, assignable to a weathering stage, were recovered from Level 9. This certainly cannot be taken as a comparable indicator of weathering processes.

On the other hand, both the table and profiles do indicate two fairly distinct depositional events. The first lies between Levels 1 and 4 and the second is evident at Levels 12 and 13. As the patterns indicate weathering Stage 1 is dominant in Level 1; however, this level is probably a mixed deflated surface, as indicated by the total proportion of the bone assemblage represented here. Levels 2 through 4 appear to have been relatively stable, with a predominance of Stage 3 in Levels 2 and 3, with Stage 2 weathering dominant in Level 4.

Table 79. Summary of weathering stages in relation to depth, from site 42SA8506 (count and row percent; total count and column/row percent).

Level and Depth (cm)			Weathering Stage 1	2	3	4	5	Sub-total	7*	Total
1	≥0	< 5	9 (56.25)	2 (12.50)	5 (31.25)	-	-	16	451	467 (36.48)
2	≥ 5	<10	1 (4.00)	3 (12.00)	21 (84.00)	-	-	25	186	211 (16.48)
3	≥10	<15	1 (2.63)	5 (13.16)	31 (81.58)	1 (2.63)	-	38	80	118 (9.22)
4	≥15	<20	1 (4.76)	9 (42.85)	6 (28.57)	5 (23.81)	-	21	54	75 (5.86)
5	≥20	<25	2 (12.50)	6 (37.50)	8 (50.00)	-	-	16	51	67 (5.23)
6	≥25	<30	2 (18.18)	4 (36.36)	5 (45.45)	-	-	11	11	22 (1.72)
7	≥30	<35	2 (66.67)	-	1 (33.33)	-	-	3	6	9 (0.70)
8	≥35	<40	-	3 (75.00)	1 (25.00)	-	-	4	11	15 (1.17)
9	≥40	<45	-	-	7 (100.00)	-	-	7	30	37 (2.89)
10	≥45	<50	1 (8.33)	2 (16.67)	9 (75.00)	-	-	12	27	39 (3.05)
11	≥50	<55	6 (18.18)	19 (57.58)	8 (24.24)	-	-	33	20	53 (4.14)
12	≥55	<60	- (30.43)	14 (26.09)	12 (43.48)	20	-	46	37	83 (6.48)
13	≥60		3 (5.56)	11 (20.37)	14 (25.93)	26 (48.15)	-	54	30	84 (6.56)
Total			28 (2.1)	78 (6.1)	128 (10.0)	52 (4.1)		286 (22.3)	994 (77.6)	1280 (100.0)

*non-assignable fragments, indeterminate Class 7.

Levels 5 through 11 are, again, somewhat problematic, given the relatively and absolutely low frequencies and proportions of bones from these levels. The overall pattern shows relatively rapid burial with intermittent surface stability and longer periods of exposure. This is most evident at Level 7, which has a predominance of Stage 1 weathering, and the increasing representation of Stages 2 and 3 descending into Levels 8 through 11. This interpretation should be taken more as illustrative rather than definitive, in view of the low frequencies of bone at these levels. However, the same low frequencies also indicate a low rate of bone deposition over time.

Levels 12 and 13 possibly represent an occupational surface of a short duration. Stage 4 weathering dominates in both levels, with considerable proportions of Stages 2 and 3.

Of interest is the total absence of Stage 5 and the very minor contribution of Stage 4 weathering to the overall assemblage. This pattern indicates fairly rapid burial of surfaces and possibly fewer deflational events than was seen in the patterning from site 42SA8502.

42SA8509

Too few bones were recovered from this site to provide any kind of patterning. However, tooth fragments were observed and the majority of fragments had been burned, indicating cultural modification of the bone. The near absence of bone is at least negative evidence for the limited importance of faunal resources at this site.

42SA8512

The overwhelming proportions of Stage 1 represented in Table 80 are evidence for a continually aggrading depositional environment at this location. It would also appear that there were possibly two separate occupations of the site, one situated between Levels 1 and 4 and another beginning at Level 7 and continuing through Level 11. In comparison to the other sites, 42SA8512 has a low representation of burned bone. Cutmarks were observed on bones from the identifiable component. Possible gnawing was also a prominent feature on identifiable bones.

42SA16858

The fragment component of this site was composed entirely of unidentifiable fragments, as shown in Table 81. Nearly a third of the fragments evidenced burning. Weathering was confined almost wholly to Stage 1, with Stage 2 well represented (Table 81). Two bones evidenced Stage 3 weathering. The absence of any further weathering would argue for quite rapid burial of the bones. The highest bone frequency was encountered in Level 5 and the second greatest bone representation in Level 15. Given the predominance of very early weathering stages, it is suggested that the aforementioned levels do not represent deflational surfaces, but are occupational events. However, there is a fairly even distribution of bone down through the levels which may indicate a fairly constant rate of bone deposition.

DISCUSSION AND CONCLUSION

While the foregoing descriptions and discussions provide a descriptive account of the patterns of bone weathering and deposition, a more specific method of determining the length of exposure of the bones from each site is available. Behrensmeyer (1978) developed a broad categorization of the relationship between time of death of an animal and the weathering stage observed. Modification of her scheme based upon observations of bone weathering rates (Burgett 1990b) results in another framework for using bone weathering called the Minimum Age of Exposure (MAE). Table 82 is taken directly from Behrensmeyer's (1978:157) research, with some minor modification.

Examining the ranges given in the above table it is interesting to observe that weathering Stages 0 and 1 cannot coexist in the same group of bones with weathering Stages 3 through 6 (given that all the bones were the same weathering stage and were deposited on the surface at roughly the same time). Neither can Stage 0 be a pristine assemblage with Stage 2 weathering. It is also evident that Stage 2 weathering has a lesser possibility of coexisting in the same assemblage as Stages 4 and 5. What this means is that when these relatively exclusive weathering stages do coexist in the same assemblage, this is evidence of redeposition (e.g., sand

dune deflation), human-produced palimpsests, or bioturbation (e.g., rodent burrowing).

Essentially, the MAE is a determination of the minimum number of years that it would have taken to produce the most weathered stage observed in a bone assemblage. In this research the units of analysis have been the arbitrary five-centimeter excavation levels and an MAE has been determined for each level. Simply put, the MAE of any given level is determined by the most advanced weathering stage observed in the bones from that level.

The four sites shown in Table 83 show a diversity of patterns of stratigraphic weathering stage representation. Site 42SA8502 has virtually all weathering stages represented at all levels, demonstrating that even if two major depositional/occupational events can be suggested from the overall profile, there are no levels with a pristine unmixed subassemblage. This pattern further demonstrates a high energy aggradation/deflation regime, as well as a high level of human and non-human activity at this site. Given the MAE for each level the possibility that there are several palimpsests throughout the stratigraphic profile is quite high.

For 42SA8506, there is considerably less mixing of weathering stages throughout the stratigraphic levels. MAE values are low, but keeping in mind the range of years possible for weathering Stages 3 and 4, there could also be several re-use episodes and deflation events represented here. Levels 3 and 4 are definitely mixed; however, the mixing is not heavy and the coexistence of weathering Stages 1 and 4 in these levels may be nothing more than vertical migration of bones in the matrix. Again, it would appear that this site also holds evidence of at least two occupation events.

Site 42SA8512 has some interesting MAE figures and overall profile. The total frequency profile suggest two occupational/depositional events and the MAE/WSC figures in Table 83 strongly support this interpretation. The relative lack of mixing, when compared to the previous two sites, does indicate that there are two primary assemblages. However, Levels 3 and 4 do have weathering Stages 1 and 4 co-represented, and this indicates a deflation/mixing event on top of the seemingly pristine Levels 5 through 7. Level 8 appears mixed; however, the one specimen of Stage 5 weathering could have been the result of bioturbation. All in all, Levels 9 through 12 also seem to indicate a pristine subassemblage. Although re-occupations within the two distinct depositional levels are a possibility, the MAE for these levels generally indicates that that possibility is low.

42SA16858 has the lowest overall MAE values of the sites in Table 83 thus further supporting the interpretation of rapid burial in an aggrading sedimentary environment. However, the low total frequency of bones and fragments at this site casts some doubt on the statistical validity of inter-level comparisons. With over 85 cm of matrix represented here, there appears to have been at least two discrete occupations at this site.

Of the remaining sites not represented in Table 83, 42SA415, 42GR913, 42SA8503, and 42SA8509, the paucity of bone at these sites demonstrates the relative unimportance of faunal resource preparation and/or consumption as activities. However, 42GR913 is quite interesting given the absence of unidentifiable fragments and the presence of only Stage 1 weathering. This would indicate that the site was buried very rapidly, probably within a year of the bones being left on the surface, and that mixing and attrition did not occur because of this. The profile presented previously would indicate a possible one-time use of the site.

Overall, mechanical attrition of once complete or nearly complete bone was of a severe degree at sites 42SA8502, 42SA8503, 42SA8506, and 42SA8512. Marrow processing, burning of bone, human trampling, and attrition by weathering have all been factors in reducing the bone to unidentifiable fragments at these sites.

In spite of the limitations of this study, as outlined previously, it is apparent that there is substantial patterning present in the relationship between the taphonomic attributes of bone fragments and their stratigraphic positions within the matrices of the examined sites. The use of unidentifiable bone fragments as an analytic method would seem to be justified, but does need refinement. This, however, requires experimental research to bracket more precisely the weathering processes that affect bone in terms of time and attrition, as well as the need for understanding the often turbulent depositional environments in which prehistoric activities occurred.

Table 80. Summary of weathering stages in relation to depth, from site 42SA8512 (count and row percent; total count and column/row percent).

Level and Depth (cm)			Weathering Stage 1	2	3	4	5	Sub-total	7*	Total
1	≥0	<5	5 (71.43)	2 (28.57)	-	-	-	7	122	129 (11.63)
2	≥5	<10	10 (83.33)	1 (8.33)	1 (8.33)	-	-	12	62	74 (6.78)
3	≥10	<15	75 (73.53)	14 (13.73)	12 (11.76)	1 (0.98)	-	102	79	181 (16.58)
4	≥15	<20	100 (88.5)	8 (7.08)	4 (3.54)	1 (0.18)	-	113	114	227 (20.79)
5	≥20	<25	16 (88.88)	2 (11.11)	-	-	-	18	36	54 (4.95)
6	≥25	<30	10 (100.00)	-	-	-	-	10	26	36 (3.30)
7	≥30	<35	8 (100.00)	-	-	-	-	8	16	24 (2.20)
8	≥35	<40	5 (71.43)	1 (14.29)	-	-	1 (14.29)	7	87	94 (8.61)
9	≥40	<45	5 (71.43)	1 (14.29)	1 (14.29)	-	-	7	91	98 (8.97)
10	≥45	<50	2 (40.00)	3 (60.00)	-	-	-	5	68	73 (6.68)
11	≥50	<55	1 (12.50)	1 (12.50)	6 (75.00)	-	-	8	28	36 (3.30)
12	≥55	<60	10 (100.00)	-	-	-	-	10	41	51 (4.67)
13	≥60		-	-	-	-	-	-	29	29 (2.66)
Totals			247 (22.33)	33 (2.98) 3.0	24 (2.17) 2.2	2 (0.18) 0.2	1 (0.09) 0.09	307 (27.76)	799 (72.24)	1106 (100)

*non-assignable fragments, indeterminate class 7.

Table 81. Summary of weathering stages in relation to the depth for site 42SA16858 (count and row percent; total count and column/row percent).

Level and Depth (cm)			Weathering Stage 1	2	3	4	5	Sub-total	7*	Total
1	>0	<5	-	1 (100.00)	-	-	-	1	1	2 (1.59)
2	>5	<10	-	-	-	-	-	-	-	-
3	>10	<15	2 (100.00)	-	-	-	-	2	2	4 (3.17)
4	>15	<20	4 (100.00)	-	-	-	-	4	5	9 (7.14)
5	>20	<25	9 (81.81)	2 (18.18)	-	-	-	11	12	23 (18.25)
6	>25	<30	3 (60.00)	2 (40.00)	-	-	-	5	6	11 (8.73)
7	>30	<35	5 (71.43)	2 (28.57)	-	-	-	7	5	12 (9.52)
8	>35	<40	3 (50.00)	3 (50.00)	-	-	-	6	3	9 (7.14)
9	>40	<45	1 (25.00)	3 (75.00)	-	-	-	4	3	7 (5.56)
10	>45	<50	3 (100.00)	-	-	-	-	3	6	9 (7.14)
11	>50	<55	2 (40.00)	3 (60.00)	-	-	-	5	2	7 (5.56)
12	>55	<60	2 (50.00)	2 (50.00)	-	-	-	4	3	7 (5.56)
13	>60	<65	1 (25.00)	1 (25.00)	2 (50.00)	-	-	4	3	7 (5.56)
14	>65	<70	2 (100.00)	-	-	-	-	2	2	4 (3.17)
15	>70	<75	6 (100.00	-	-	-	-	6	6	12 (9.52)
16	>75	<80	-	-	-	-	-	-	1	1 (0.79)
17	>80		2 (100.00)	-	-	-	-	2	-	2 (1.59)
Total			45 (35.7)	19 (15.1)	2 (1.6)	0 (0)	0 (0)	[66] (52.4)	60 (47.6)	126 (100)

Table 82. Relationship between weathering stages and the number of years needed to produce those stages.

Weathering Stage	Years Since Death
0	0 - 1
1	0 - 3
2	2 - 6
3	4 - 15+
4	6 - 15+
5	8 - 15+
6	?

Table 83. Minimum age of exposure.

Level	42SA8502		42SA8506		42SA8512		42SA16858	
	MAE	WSC	MAE	WSC	MAE	WSC	MAE	WSC
1	6	1 - 5	3	1 - 3	2	1 - 2	2	2
2	6	1 - 5	3	1 - 3	3	1 - 3	-	-
3	6	1 - 5	6	1 - 4	6	1 - 4	0	1
4	6	1 - 4	6	1 - 4	6	1 - 4	0	1
5	6	1 - 4	3	1 - 3	2	1 - 2	2	1 - 2
6	6	1 - 5	3	1 - 3	0	1	2	1 - 2
7	6	1 - 5	3	1,3	0	1	2	1 - 2
8	6	1 - 5	3	2 - 3	2,6	1,2,5	2	1 - 2
9	6	1 - 5	3	3	3	1 - 3	2	1 - 2
10	6	1 - 5	3	1 - 3	2	1 - 2	0	1
11	6	1 - 4	3	1 - 3	3	1 - 3	2	1 - 2
12	6	1 - 4	6	2 - 4	0	1	2	1 - 2
13	6	1 - 4	6	1 - 4	- -		3	1 - 3
14							0	1
15							0	1
16							-	-
17							0	1

MAE = Minimum Age of Exposure.
WSC = Weathering Stage Classes present in the level.

ARTIFACT DISPLACEMENT ANALYSIS

> The archeological landscape is a developmental phenomenon, and archaeologists must make their peace with this fact. Beyond this, the evolving nature of the archaeological record must be embraced and utilized, for the patterning that develops in the archaeological record as a result of its formation provides critical clues to the pose and operation of cultural systems as they interact with the natural, cultural, and social landscape.
>
> Wandsnider 1989:369

INTRODUCTION

How materials discarded by humans change in character and context through time has become a topic of study that transcends theoretical approaches in anthropological archeology. Identifying variables that are of importance to gaining some insight into the history of these artifact assemblages (i.e., formation processes) is, as Wandsnider (1987:150) aptly notes, " an immature avocation in archaeology." Nevertheless, the growth of the study of formation processes contributes to the study of the organization of prehistoric cultural systems and promotes it as a productive line of research in anthropology.

The present study reports an empirical investigation of artifact behavior in eight microenvironments that vary in geomorphological position, yet are influenced by climatologically similar factors. Those conditions that determine the surface displacement of lithic artifacts with varying attributes yield variables that permit the exploration of relationships between these flakes, their movement, and the variability in their geomorphological position on the landscape. Environmental conditions that were considered to affect artifacts in these different microenvironments include precipitation, temperature, wind direction, and wind velocity. The complex relationships between artifact attributes, geomorphological position, and climatic conditions were investigated to ascertain the extent to which displacement from the original position of discard was influenced by the effects of long-term environmental conditions.

The integrity of the archeological record is a fundamental dimension of research and a unique problem in anthropological archeology. Numerous studies have been conducted since the 1970s concerning the effects of the physical environment and animal (including human) activities on our interpretations of archeological remains. The effects of natural processes on the archeological record in arid and semi-arid regions is of special interest because the ground surface yields a highly visible archeological record. These surface remains are therefore considered potentially useful in assessing behavioral manifestations of adaptations in the past.

The spatial configuration of artifacts and their association with other cultural and natural features is used often to build interpretative scenerios of activities at sites (e.g., Stiger 1986; Wallon 1984; cf. O'Connell 1987). Wandsnider (1989) emphasizes that the archeological record cannot be viewed as being formed through simple accumulation of debris from cultural activities, but rather through the interaction of cultural and natural processes on artifact assemblages. That is, an exposed archeological assemblage is a source of material for human activities and vulnerable to disturbance by natural processes.

The research of previous investigators suggests that predicting artifact movement on the basis of artifact attributes and/or the microenvironment of the artifact is complex. A thorough review of experimental studies of natural formation processes on lithic materials has been provided by Wandsnider (1989:398-423). No attempt is made here to reiterate this review; however, several of these experiments have examined the displacement of artifacts introduced into dune systems. With few exceptions, the studies have to date reported the effects of natural processes in limited time frames (e.g., Shelley and Nials 1983; Simms 1984b).

Long-term behavior of artifactual materials has been assessed using simulation techniques (e.g., Bowers et al. 1983; Wandsnider 1989). The time frame upon which actual experimental data is collected for simulation trials is, however, critical to the interpretation of these long-term movement sequences. Wandsnider (1988, 1989) emphasizes geomorpological research that suggests the behavior of introduced objects on a land surface is likely to be highly active until the surface reaches a stable equilibrium and the objects "settle-in" (e.g., up to one year).

Fundamental questions that arise when observing the variable density of artifacts visible on the surface in southeastern Utah include: how do meteorological conditions in this environment affect the integrity of archeological assemblages; and secondly, is there some predictive means by which we can assess the state of assemblage integrity when attributes of artifacts, ground surface, and meteorological conditions are known (see Wandsnider 1988:20)?

This study was designed as an inductive investigation of the effects of natural processes on the archeological record to provide a foundation for assessing the spatial integrity of the ubiquitous lithic material assigned spatial coordinates along the road corridor. It should be emphasized that this research focused on the impact of non-human induced variables on artifact position. The impacts of human and animal activities on artifacts have been assessed in various other experimental studies (e.g., Gifford-Gonzalez et al. 1985; Pryor 1988; Yorston et al. 1990) as well as that impact resulting from domestic animal behavior (e.g., Osborn, Vetter, Hartley, Walsh, and Brown 1987). Livestock grazing is currently prohibited in this district of the park and the experimental stations were situated so as to minimize potential disturbance by park visitors and staff.

PREDICTIONS

Previous studies of artifact movement in arid to semi-arid environments allow for several expectations about the horizontal displacement of lithics along the Island-in-the-Sky road corridor. Much of the previous empirical investigation concerning artifact movement in the American Southwest has focused on sand dune geomorphology, because of their observed change and the high number of "lithic scatters" observed under these conditions. The geomorphological history and current conditions of the Island-in-the-Sky area permit the assessments of these experiments to be used as comparative data in establishing some understanding of assemblage integrity in this environment. Expectations for this study are summarized as follows:

(I) The effect of natural processes (precipitation, temperature, wind) resulting in artifact movement are assumed to vary with the degree of exposure to these factors. Vegetation characteristics of the ground surface are also known to affect aeolian processes (Thomas 1988). It is expected that the total displacement of each class of artifact by size will vary significantly between the eight different microenvironments studied in this research. The attribute of size is used predominantly in these analyses, because size is recognized as a determining factor in the life-history of the artifact in terms of cultural forces (i.e., discard and loss) and geomorphological forces that operate on subsequent incorporation of the artifact into sediments (see Schiffer 1983, 1987:267-269; Wandsnider 1987, 1988).

(II) Geomorphological study suggests that the movement of introduced particles to a surface is greatest during the first few weeks after placement, subsequently becoming more spatially stable as part of the surface context (Wandsnider 1988, 1989). It is expected that displacement of artifacts will be greatest at all eight experimental stations during the first period (seven months) of monitoring.

(III) Artifact movement is expected to vary differentially, based on morphological characteristics of lithic material. It is expected that the degree of movement of lithic artifacts will be conditioned by the size and weight of the artifacts.

We have found that the smaller artifacts show greater horizontal movement in all eight microenvironments.

METHODOLOGY

In March of 1984 manufactured flakes were systematically placed at eight experimental stations near and along the road corridor in the Island-in-the-Sky District. Each station contained a systematic arrangement of thirty-eight flakes produced from reddish chalcedony from the Cedar Mesa formation, "Cedar Mesa chert." Station 4 was plotted with only thirty-seven flakes due to an error in field placement. Prior to field placement each artifact was weighed, its maximum length and width recorded, and size graded into five classes.[1] This artifact assemblage was sorted using a variable size grid template drawn on K and E metric scale paper. Individual pieces were moved across this template until their total surface area most closely approximated that for a particular size. Table 84 reports the mean dimensions for each size grade used in the experiment.

Each station was plotted with an equal number of artifacts per size grade. Experimental plots were laid out on intersecting axes of one meter length, forming a 2-m x 2-m surface from which to orient measures of movement (cf. Bowers et al. 1983; Nash and Petraglia 1984). Steel spikes were used to mark the end of each one-meter axis as well as the intersection of the X and Y axes. The Y axis was aligned with magnetic north using a Brunton field compass.

Artifacts were positioned along each axis at 10-cm intervals. Each flake was situated so that the long axis of the artifact lay perpendicular to the up-down slope of the experimental plot. Flakes were numbered with India ink and coated with clear lacquer polish. This artifact number faced the ground surface to avoid deteriorating effects of the sun, as well as to minimize attention to the experimental station by park visitors. Subsequent measurements of displacement were made using portable meter grid frames subdivided into one hundred 10-cm x 10-cm cells. A photographic record, including black/white and color photographs, was kept of each station. This documentation also included photographs taken of each cardinal direction from the experimental station.

The coordinates of each artifact's position were measured five times between March 1984 and October 1989. The frequency or intervals for these observations could not be predetermined at the outset of the experiment (cf. Wandsnider 1988:19; 1989:44). Unfortunately, periods between artifact observations ranged from approximately seven to twenty-five months. Measures were made by Susan Vetter, often with assistance from a member of the park staff when circumstances permitted. However, all stations were examined and artifacts measured on the same day or consecutive days, and not independently of each other.

The analysis reported here is of the horizontal movement of these artifacts. Some flakes, however, were buried by natural processes, and some buried items subsequently reappeared on the surface. A summary of

Table 84. Artifact assemblage by size grade.

Size Grade	N	$\bar{x}$ length (cm)	$\bar{x}$ width (cm)
1	24	6.01	3.81
2	40	4.18	2.71
3	64	3.18	2.16
4	88	2.29	1.57
5	88	1.51	1.27

Table 85. Mean meteorological data by time period between artifact measures.

Period (dates)	Wind Direction*	Wind Velocity (mph)	Low Temp. (F)	High Temp. (F)	Precip. (in.)
1 (3/84-11/84)	163.4	6.2	47.4	68.5	1.35
2 (11/84-10/85)	43.9	6.1	42.2	62.8	1.08
3 (10/85-6/86)	121.6	6.2	36.2	56.6	.53
4 (6/86-9/87)	108.3	5.2	45.1	66.0	.84
5 (9/87-10/89)	72.3	2.3	38.9	61.3	.55

* Expressed in degrees from north

the rate and frequency of artifact burial for each of the eight microenvironments studied is presented below.

Meteorological data were compiled from daily records kept by park staff using instruments located on the Island-in-the-Sky near the current visitor contact station. The data used here dates from March 1984, when the experimental stations were introduced, to May of 1990, encompassing the overall period in which the experimental stations were monitored. These daily records are logged on National Oceanic and Atmospheric Administration forms (WS Form E-15) that record temperature, precipitation and water equivalency, and wind data. Wind data were described using cardinal directions. Cardinal direction was translated to degrees from north for the purposes of computing. When the wind velocity was recorded as "calm"by park staff, direction was recorded as "0." Wind data are complete for all days except for the period from March to September 1988, during which time instruments were inoperable. Table 85 summarizes the data used in these analyses by period for each observation.

EXPERIMENTAL STATIONS

Placement of the eight experimental stations in the Island-in-the-Sky District was conditioned by several factors. First, stations were located in diverse microenvironments, but representative of those surfaces where similar prehistoric materials are observed; consequently many are located near prehistoric sites along the road corridor referred to elsewhere in this report. Second, experimental stations were positioned so that the likelihood of disturbance by park visitors would be minimized, yet access to the stations would allow for subsequent and repeated artifact observations.

Brief descriptions of these experimental stations follow:

(1) This station lies approximately 75 m from the current roadway east of 42SA8506. Sombrero Butte lies approximately 94 degrees east of the experimental station. Indian rice grass and western wheat grass cover the ground surface. Approximately 7 m to the north of the unit is a 2.3-m juniper; 6 m to the southwest, a 5.5-m juniper; and 9 m southeast, a 1.3-m juniper (Figure 133).

(2) This station is located just off Mesa Arch Trail approximately 3 m southwest of the canyon rim. The unit lies in an open area surrounded by blackbrush and pinyon and juniper within 10 m of the station to the west, south, and east. A fallen dead pinyon is just to the southeast. Sandy soil with abundant sandstone pebbles characterizes the surface that gradually slopes to the south (Figure 134).

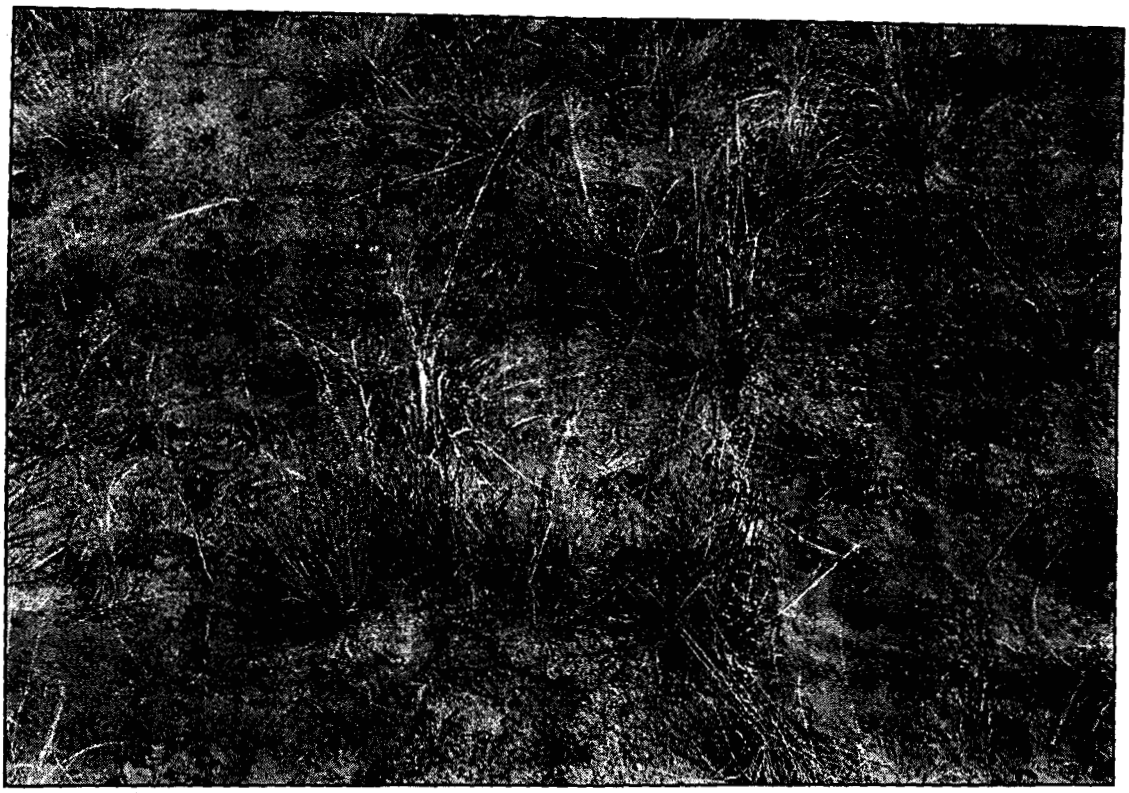


Figure 133. Overview of Experimental Station 1 looking east.

(3) The third experimental station lies west of Aztec Butte and is positioned in cryptogamic soil that slopes approximately 10 percent to the east (Figure 135).

(4) This station lies approximately 240 m east of the road to Grandview Point, about one quarter mile from the "Wye." A peaked butte of Navajo Sandstone is just to the east, and 42SA3279 lies just to the south of this formation. The unit lies in a clearing of sand dunes among surrounding juniper. Scattered blackbrush, bird's beak, blue grama grass, and prickly pear characterize the area (Figure 136).

(5) This station is located 123 m west of the road in Gray's Pasture and north of the corral at site 42SA8515. Indian rice grass, western wheat grass, and blue grama grass characterize the immediate station. A patch of mormon tea lies about 3 m northwest of the unit, along with a rodent burrow (Figure 137).

(6) Station six is situated in a patch of cryptogamic soil that is level but positioned on a small rise surrounded by slickrock. The road is located 75 m to the east, near the Neck and near excavations at 42SA8502. The canyon rim lies approximately 25 m to the south. Live juniper exist at the extreme end of the eastern (X) axis and also approximately 2 m to the west. Narrow-leaf yucca and opuntia are also prevalent on this small rise with a pinyon pine about 5 m to the northwest (Figure 138).

(7) Approximately 27 m south of Station 6 lies Station 7. This station is positioned on slickrock that slopes slightly to the southwest and is surrounded by pinyon trees 3.5 to 18 feet high on the east, southeast, southwest, and west. The canyon rim lies 35 m to the northwest (Figure 139). Dots of red paint were used to mark axis ends and the intersection on this slickrock.

(8) This station is situated in a sand dune area approximately 75 m west of the road. The station is positioned in a dished-out area about 10 m in diameter around a pinyon tree. The tree lies about one meter south of the experimental station. The south and southwest sides of the "blow-out" tend to have greater sand accumulation. Indian rice grass, mormon tea, and surrounding blackbrush characterize the vegetational environment. An additional pinyon pine lies downslope about 5 m to the north (Figure 140).

Figure 134. Overview of Experimental Station 2 looking east with Washer Woman and LaSal mountains in the background.

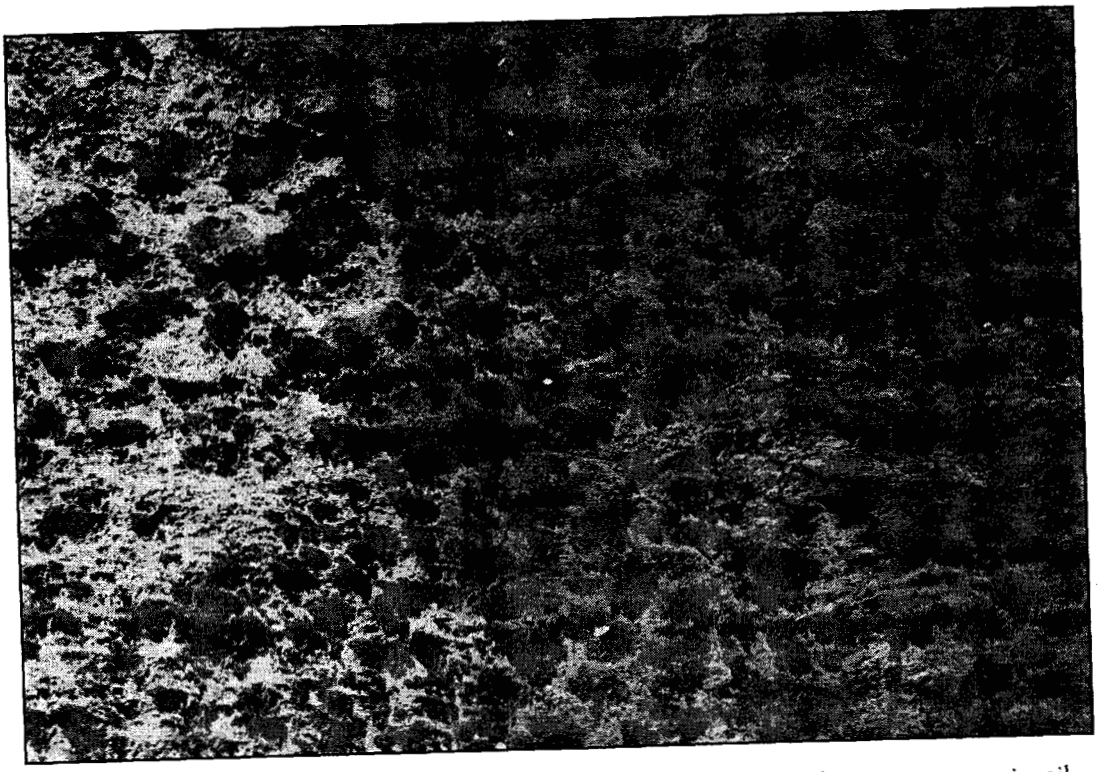


Figure 135. Overview of Experimental Station 3 looking west and upslope showing cryptogamic soil.

Figure 136. Northwestward view of Experimental Station 4 during initial artifact placement.

Figure 137. Overview of Experimental Station 5 looking east.

Figure 138. Overview of Experimental Station 6 looking north.

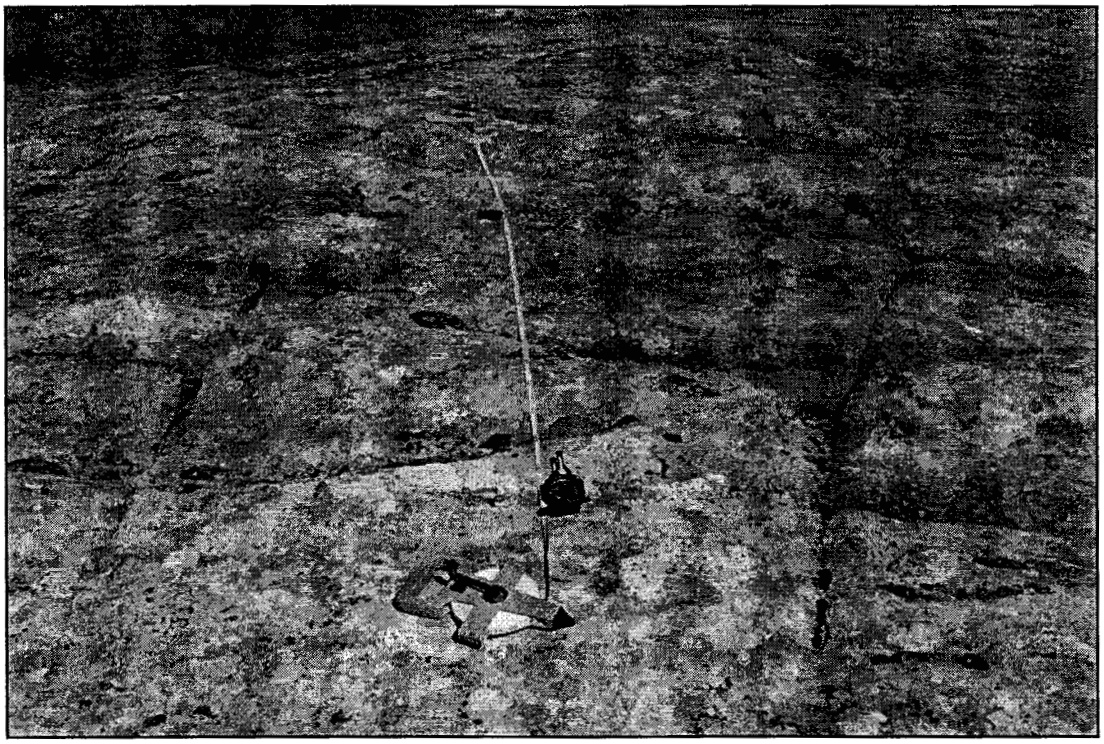


Figure 139. Overview of Experimental Station 7 established on slickrock with tape on north-south axis.

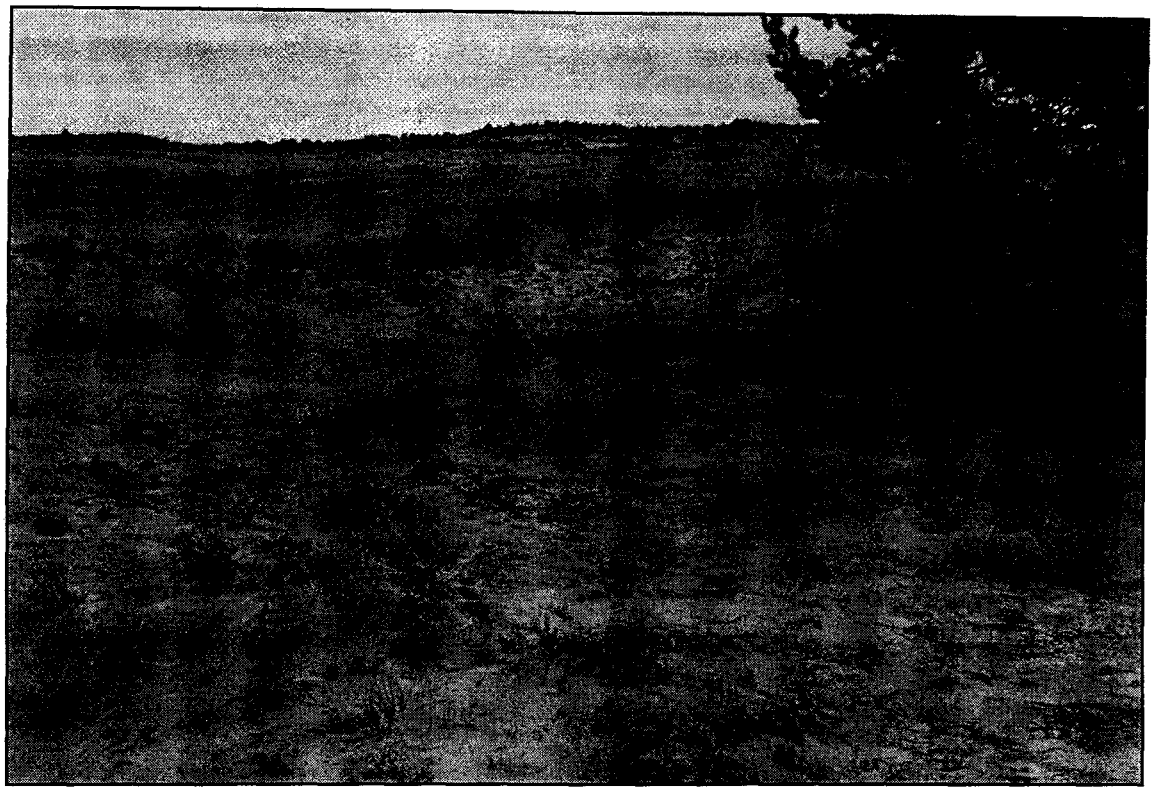


Figure 140. Overview of Experimental Station 8 with road in background.

ANALYSES

The effects of natural processes (precipitation, temperature, and wind) on artifact movement are expected to vary with the surface on which the artifacts are placed. The interaction of these variables is, however, complex. Wandsnider (1989:62) outlines a complex set of interactions between artifact attributes, geomorphological variables, and meteorological variables. Although fewer sets of variables are considered, the question of interest here is how a basic set of meteorological variables affect movement of artifacts of various sizes in different microenvironments. This data was subjected to the least squares method of multiple regression analysis using SPSS-PC version 3.0 (cf. Wandsnider 1989).

Tables 86 and 87 report partial correlation coefficients that reflect the effects of these meteorological variables on the movement of artifacts by size and experimental station during the overall experimental period. These two sets of independent variables were constituted so as to minimize their correlation with each other. Precipitation, wind direction and velocity, and temperature are, of course, highly related in terms of meteorological and climatological dynamics. The effect of temperature on artifact movement is difficult to assess intuitively in this environment. However, we do know that in cold deserts there exist extreme seasonal differences in temperature and that temperature variation is often associated, in many complex ways, with precipitation and wind velocity. Precipitation, as used in these analyses, includes the water equivalency of snowfall.

The strong correlation between mean high temperature and mean low temperature, when used together as independent variables in multivariate analyses, can result in substantial computational problems, reflected in "tolerance" measures (very low) of the partial correlation coefficients. Therefore, because temperature is fundamentally a reflection of seasonality and because the periods between artifact observations cross-cut seasons in this environment we chose to use mean high temperature and mean low temperature separately with precipitation and wind data to help assess the effect of temperature on artifact displacement, when controlling for wind velocity and precipitation.

Table 86. Partial correlation coefficients and r^2 from analysis of meteorological variables and distance moved by artifact size and experimental station for all periods (analysis conducted with mean high temperature data).

Experimental Station	Artifact Size	Wind Velocity	Precipitation	High Temperature	r^2
1	1	0.06378	0.12008	-0.30697	0.21462
1	2	-0.80729	0.20068	-0.31321	0.78986
1	3	-0.42826	-0.92933	0.78568	0.96336
1	4	-0.60837	0.13710	-0.49620	0.69807
1	5	-0.78626	0.98481	-0.95819	0.98639
2	1	0.99980	-0.99985	0.99992	0.99986
2	2	0.91164	-0.94984	0.95418	0.91186
2	3	0.25358	-0.08357	0.07476	0.09085
2	4	-0.96961	0.69233	-0.67762	0.96262
2	5	-0.88191	0.20122	0.53777	0.90115
3	1	-0.90452	0.33409	-0.18058	0.88967
3	2	-0.45459	-0.44839	0.27380	0.70239
3	3	-0.95713	0.97563	-0.95159	0.95945
3	4	-0.73963	0.63393	-0.69395	0.61283
3	5	-0.98380	-0.93596	0.93673	0.99276
4	1	0.70287	-0.82011	0.80597	0.67746
4	2	-0.61892	-0.10479	-0.47057	0.80852
4	3	-0.71022	0.50951	-0.46816	0.52260
4	4	0.53539	-0.63729	0.62402	0.41275
4	5	-0.97566	0.87529	-0.90975	0.96646
5	1	-0.21616	0.54431	-0.34061	0.46676
5	2	-0.17235	-0.59350	0.56649	0.64022
5	3	-0.89510	-0.93499	0.94836	0.97785
5	4	-0.40666	-0.57817	0.55717	0.73136
5	5	-0.59718	-0.68420	-0.15640	0.92337
6	1	-0.57074	0.17346	-0.88244	0.94266
6	2	-0.63029	0.83687	-0.17080	0.90985
6	3	0.36041	-0.61997	0.62797	0.43161
6	4	0.38175	-0.88202	0.80515	0.86835
6	5	0.70541	-0.84023	0.82473	0.71320
7	1	0.79192	0.13045	-0.30422	0.81974
7	2	-0.98732	0.95570	-0.90649	0.97796
7	3	-0.99245	-0.99964	0.99977	0.99980
7	4	0.32377	-0.61101	0.49966	0.44943
7	5	-0.16811	0.49839	-0.16830	0.53687
8	1	0.34439	-0.48673	0.52983	0.27200
8	2	0.26869	-0.30275	0.46615	0.29079
8	3	0.52389	-0.82188	0.84818	0.74781
8	4	0.11461	0.25057	-0.13568	0.26605
8	5	0.93888	-0.28597	-0.63607	0.94843

Table 87. Partial correlation coefficients and r^2 from analysis of meteorological variables and distance moved by artifact size and experimental station for all periods (analysis conducted with mean low temperature data).

Experimental Station	Artifact Size	Wind Velocity	Precipitation	Low Temperature	r^2
1	1	0.20707	0.03946	-0.23614	0.18126
1	2	-0.82174	0.12522	-0.24251	0.78070
1	3	-0.72990	-0.94633	0.82906	0.97007
1	4	-0.61231	0.17503	-0.55871	0.72449
1	5	-0.25332	0.97716	-0.93455	0.97895
2	1	0.97856	-0.99278	0.99626	0.99356
2	2	0.89813	-0.97029	0.97360	0.94872
2	3	0.30190	-0.14782	0.14791	0.10574
2	4	-0.97837	0.73808	-0.72988	0.96770
2	5	-0.92045	0.30107	0.47430	0.89222
3	1	-0.92918	0.39884	-0.25243	0.89321
3	2	-0.56611	-0.50870	0.34380	0.71630
3	3	-0.91684	0.96390	-0.92640	0.93915
3	4	-0.65986	0.56735	-0.63911	0.55824
3	5	-0.98733	-0.90655	0.90845	0.98967
4	1	0.63159	-0.85640	0.84732	0.74040
4	2	-0.56951	-0.20371	-0.40440	0.79428
4	3	0.47402	-0.68605	0.67980	0.48270
4	4	0.47402	-0.68605	0.67980	0.48270
4	5	-0.98343	0.90936	-0.93782	0.97655
5	1	-0.17001	0.59983	-0.40884	0.49760
5	2	-0.39926	-0.64447	0.62557	0.67753
5	3	-0.97436	-0.95948	0.96912	0.98661
5	4	-0.60046	-0.52129	0.49458	0.70571
5	5	-0.61905	-0.72862	-0.08333	0.92199
6	1	-0.12948	-0.01311	-0.84545	0.92610
6	2	-0.68661	0.86233	-0.24281	0.91261
6	3	0.21847	-0.66944	0.68351	0.49997
6	4	0.05866	-0.90878	0.84659	0.89397
6	5	0.62148	-0.87449	0.86409	0.77281
7	1	0.85348	0.05071	-0.23333	0.81217
7	2	-0.99211	0.97015	-0.93509	0.98447
7	3	-0.98537	-0.99267	0.99547	0.99604
7	4	0.24056	-0.66168	0.56202	0.49801
7	5	-0.17305	0.55854	-0.24034	0.55090
8	1	0.25850	-0.54067	0.58125	0.33947
8	2	0.18359	-0.35467	0.52996	0.34838
8	3	0.23006	-0.85975	0.88484	0.80492
8	4	0.20714	0.19516	-0.06244	0.25520
8	5	0.95802	-0.38565	-0.57759	0.94228

When there exists an interaction effect between independent variables it does not make much sense to interpret the separate (or main) effects, since the independent variables do not operate independently of one another with respect to their effects on the dependent variable; i.e., artifact movement (Kleinbaum and Kopper 1978:180). Furthermore, since independent variables are usually correlated, we can seldom be sure that all relevant variables are included. Therefore, as Wesolowsky (1976:51) emphasizes, we can "rarely assume that the regression coefficients we obtain are unbiased estimators for the regression parameters." Regression coefficients for each analysis are presented in the right-hand column of Tables 86 and 87.

An examination of the partial correlation coefficients is advantageous here in order to assess previously outlined predictions of artifact behavior and natural processes. A justifiable means by which to interpret the figures for each multivarite analysis (row data) can be shown by this example: the partial coefficient .79192 between artifact displacement Size Grade 1 in Experimental Station 7 and mean daily wind velocity for all periods measured, controlling for mean precipitation and mean high temperature, indicates that mean wind velocity accounts for almost 63 percent of the variance in this particular artifact displacement, controlling for the effects of precipitation and temperature during the same time of year.

The partial correlation coefficients reported in Tables 86 and 87 represent a measure of the strength of the linear relationship between two variables after controlling for the effects of the other independent variables. This measure requires the calculation of which one of the three independent variables emerges as the largest partial. However, as Gordon (1968) points out, the variables emerging with the largest partials are in actuality simply those that are the least redundantly represented. The amount of variance explained by a given variable (large or small) is strictly a function of the number of other predictor variables accompanying it in the equation, as well as the correlations among all the variables being used (Kleinbaum and Kopper 1978:163; Marascuilo and Levin 1983:102). Use of partial coefficients requires that some theoretical connection be made and that, as a consequence, the researcher must assume some knowledge concerning the presumed causal priority of the independent variables being assessed. "There is nothing more fundamental about a partial, as compared to a zero-order association, unless a good theory makes it so" (Gordon 1968:594).

With these considerations in mind, some general patterns in the effects of these basic natural processes on artifacts of various sizes in different microenvironments can be gleaned from Tables 86 and 87. One pattern apparent here is that temperature often plays a minor role, if any, in artifact movement, and in some cases acts as a suppressor variable, inhibiting the strength of the relationship between the other variables. Larger size artifacts (i.e., Size Grades 1-3) are, however, somewhat affected by temperature, although no geomorphological similarity between experimental stations is apparent where this effect occurs.

Wind velocity and precipitation, as may be expected, dominate in effects on artifact movement, with wind velocity showing a slightly stronger role than precipitation. Precipitation influenced movement of artifacts of a wide range of sizes in grass-covered stabilized dune surfaces (Experimental Stations 1, 4, and 5) and in cryptogamic soil (Experimental Station 6). Effects of precipitation on artifacts on slickrock (Experimental Station 7) are also apparent, but strongest on small artifacts (Size Grades 4 and 5), when controlling for the effects of wind velocity and both mean low and high temperature. Wind velocity shows strong association with artifact movement within a broad range of artifact sizes in sandy vegetated surfaces (Experimental Stations 1,2, and 4), and it is especially strong at Station 3 (cryptogamic soil), irrespective of temperature conditions. It should be emphasized, however, that both precipitation and wind velocity show strong effects at Station 3, when controlling for each other and temperature.

Analysis of variance procedures were used to ascertain significant differences in the distances moved for each size grade at each experimental station during each of the five measurements (time periods). The Tukey procedure was used in these analyses as the follow-up test because of its power in pairwise comparisons (Keppel 1982:153-159). Artifact movement in Station 7 was significantly different ($p < .05$) from that of other stations in the case of at least one artifact size in multiple time periods. Table 88 shows the artifact size grades for which the difference in mean distance moved between Station 7 and all others by period was statistically significant. Of primary interest here is the size grades for which this difference exists. Size Grade 4 is shown to be the most prevalent in terms of its statistical difference in mean distance moved through time. The small size of these artifacts likely accounts for this activity in all microenvironments studied. However, the

absence of Size Grade 5 in each column of Table 88 beyond that of Period 1 also reveals the vulnerability of small artifacts to the natural processes of the cold desert environment. Figure 141 shows that Size Grade 5 was most often buried in sediments of each station, when compared to all other size grades.[3] The variance in burial of these artifacts by weight is shown in Figure 142. Those artifacts in the 0-2 g category are those most likely to be buried in all experimental stations observed. Wandsnider (1987, 1988, 1989) also found that, in general, small artifacts are more often buried than are larger artifacts but that this tendency is enhanced by the compactness of the substrate. These analyses suggest that the smaller the artifact the more likely it is to not be visible on the surface regardless of the microenvironment and that movement prior to burial is greater than that of artifacts of a larger size.

The greatest movement during each observation is characterized, for the most part, by those of the smallest size (Figures 148-155). One exception is during Period 4 (June 1986 - September 1987), during which time larger, heavier artifacts moved substantially, relative to other size grades, at Stations 2 and 4. Both of these surfaces are sparsely vegetated. However, it can also be noted that large size grades also moved a greater distance, relative to other sizes in cryptogamic soil (Station 6; see also Station 3).

Table 88. Artifact size grade for which there is a significant difference ($p \leq .05$) in mean artifact movement between Experimental Station 7 and all other stations by time period.

Time Periods	Experimental Stations						
	1	2	3	4	5	6	8
1	3,4,5	3,4,5	4,5	3,4,5	3,4,5	3,4,5	4,5
2	4	4	4	4	4	4	-
3	3	-	3	3	3	1,3	-
4	4	4	4	4	4	4	4
5	-	-	4	4	4	4	4
All Periods	2,3,4,5	3,4,5	2,3,4,5	2,3,4,5	3,4,5	2,3,4,5	4,5

Artifact movement across the eight microenvironments studied appears to be quite variable (Figures 143, 144, 145, and 146). Figure 147 shows this movement by size grade and weight. Station 7, an experiment of artifact displacement on slickrock, is, not surprisingly, the surface on which movement was greatest when all measurements are compiled. Artifacts in Stations 3, 4, and 6 show the least overall displacement. Two of these experimental stations (3 and 6) are positioned in cryptogamic soil, and Station 4 lies in stabilized sand near the base of vertical Navajo sandstone rock.

Similar to the results of Wandsnider's study, the mobility of artifacts in all microenvironments studied here was not significantly greater during the first period of observation (March 1984 - November 1984) than in later periods. As Wandsnider (1989:44) points out "Artifacts in an aeolian context may be repeatedly subjected to destablizing forces and so may never come to an equilibrium position within the surface system." On the other hand, she presents evidence that an experimental study of less than ten years may be insufficient to detect a "settling-effect,"considered by some geomorphologists to be characteristic of particles introduced to a surface.

Multivariate analysis of variance was used in a nested design to hypothesize that there was no difference in distance moved by artifacts of the five size grades within the eight experimental stations across all five

time periods of observation. A statistically significant difference (Pillai's = .68816, $p < .0005$) between the mean distance moved by artifact size within stations across the five time periods was found. Univariate analysis results for all periods show a significant difference ($p < .05$) in artifact movement by size in all stations, with the exception of Periods 2 and 3 (see Table 89). No apparent meteorological cause for this lack of significance is available from the kinds and scale of variables used here. It may be worth noting that, in fact, average wind velocity for both Period 2 (12 months) and Period 3 (8 months) was over six miles per hour, greater by nearly two miles per hour than the mean wind velocity over the entire duration of the experiment. Furthermore, mean precipitation for Period 2 (1.08 in per month) was the second highest of the five monitoring periods.

represented in surface assemblages, due to their greater potential for burial. Wandsnider's (1989:16) long-term simulation analysis suggests that the amount of dispersion an assemblage incurs is related to the size distribution of that assemblage. The dispersion depicted in these experiments is therefore potentially greater than that of an assemblage of approximately the same size artifacts deposited at any one point in time, due to the broad range of artifact sizes comprising each station.

(2) The spatial integrity of artifactual assemblages on the Island-in-the-Sky is sensitive to the microenvironment in which they were deposited. Artifact displacement, however, does not detract from the spatial information inherent in these assemblages, when interest in patterns is on the order of 0.5 to 1 square meter (cf. Wandsnider 1988, 1989). The only exception to this generalization occurs when an artifact assemblage is deposited on slickrock, a phenomenon not characteristic of sites located along the road corridor in the Island-in-the-Sky. Mapping of artifacts within one- meter-diameter units along the road corridor, therefore, permits an accurate spatial depiction of culturally deposited materials, when not controlling for the effects of prehistoric and contemporary cultural processes or domestic grazing.

Table 89. Univariate F-tests by period.

Period	F	Sig.
Period 1	3.37973	.000
Period 2	1.45560	.070
Period 3	.76751	.797
Period 4	1.86956	.006
Period 5	1.51747	.05

CONCLUSIONS AND IMPLICATIONS

One of the fundamental goals of this experiment was to assess the spatial integrity of lithic assemblages found in the study area. This assessment was needed to help establish the scale at which the surface density and diversity of artifactual materials might most profitably be analyzed. Results of this experiment permit two generalizations that are pertinent to this study:

(1) The smaller the artifact, the more mobile that artifact will be through time, irrespective of the microenvironment. Smaller artifacts will be under-

The experimental stations described here remain in place. Hence, the mapping of horizontal

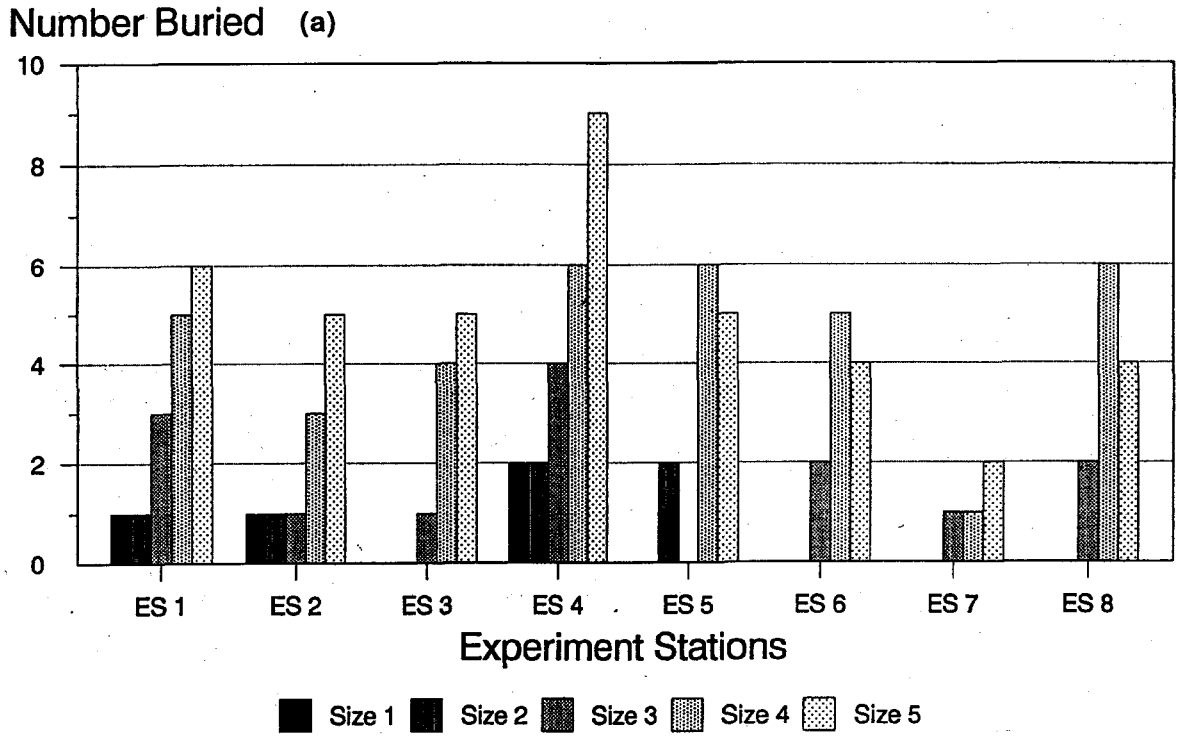
placement can be monitored indefinitely. Potentially more advantageous might be the systematic excavation of these plots to compile vertical data on artifact movement. This combined horizontal and vertical information can then be converted to data that allow systematic comparison with Wandsnider's data base and used as baseline data for incorporation into long-term simulation analysis. Only by continuing analysis of the effect of natural processes on artifact assemblages will we confidently be able to adjust our scales of spatial analysis in different environments.

Notes

[1]The assemblage of artifacts used in this experiment were categorized by weight in 2-gram increments up to 18 grams, with those weighing more than 18 grams included as one category. Descriptive analysis of artifact behavior by weight is presented here as comparative data only. Some statistical tests could not be justifiably considered here because not all weight classes were represented at all stations. No artifacts weighing 12-16 grams were found in the assemblage, with the exception of one flake (13.7 g) placed at Station 7 that has moved a total of 18.05 cm to date.

[2]Cryptogamic soil is a microbiotic crust formed by cyanobacteria that, because of their ability to stablize soil particles, capture nutrients and retain moisture. These characteristics allow them to colonize areas of bare rock and soil, forming a surface mass that is ubiquitous in the semi-arid cold desert of the Colorado Plateau.

[3]The "burial" of an artifact in this study is defined as being a minimum of fifty percent below surface at time of observation.



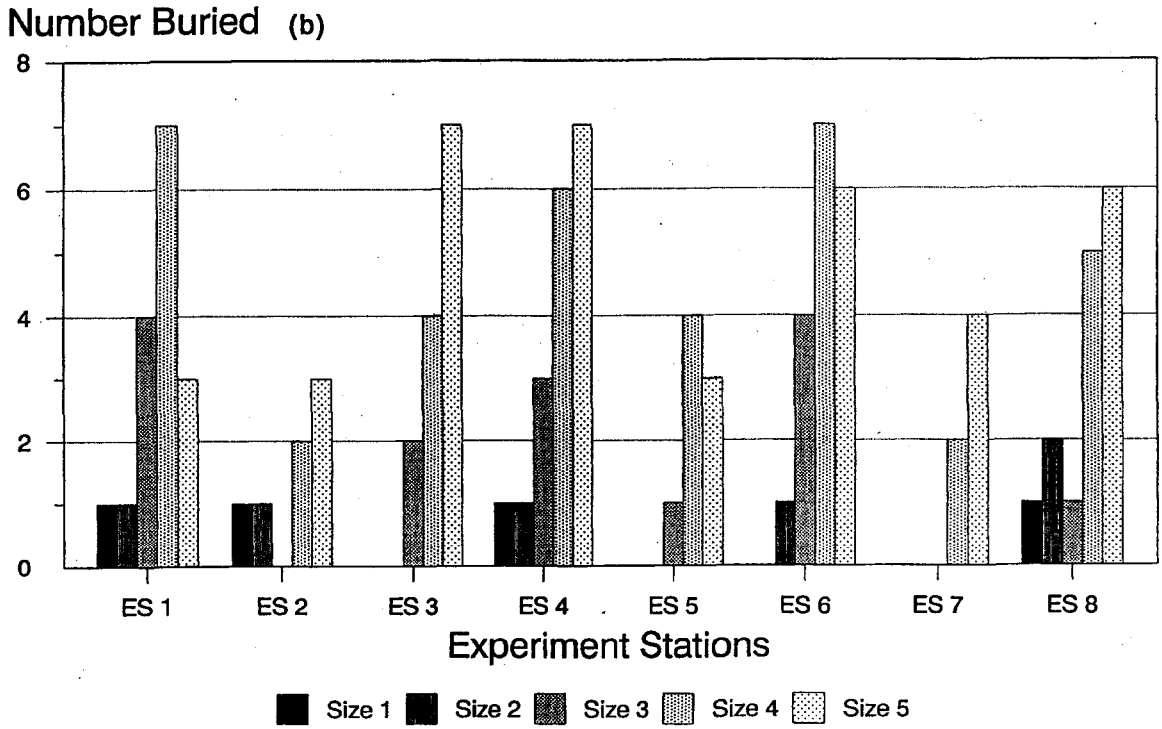
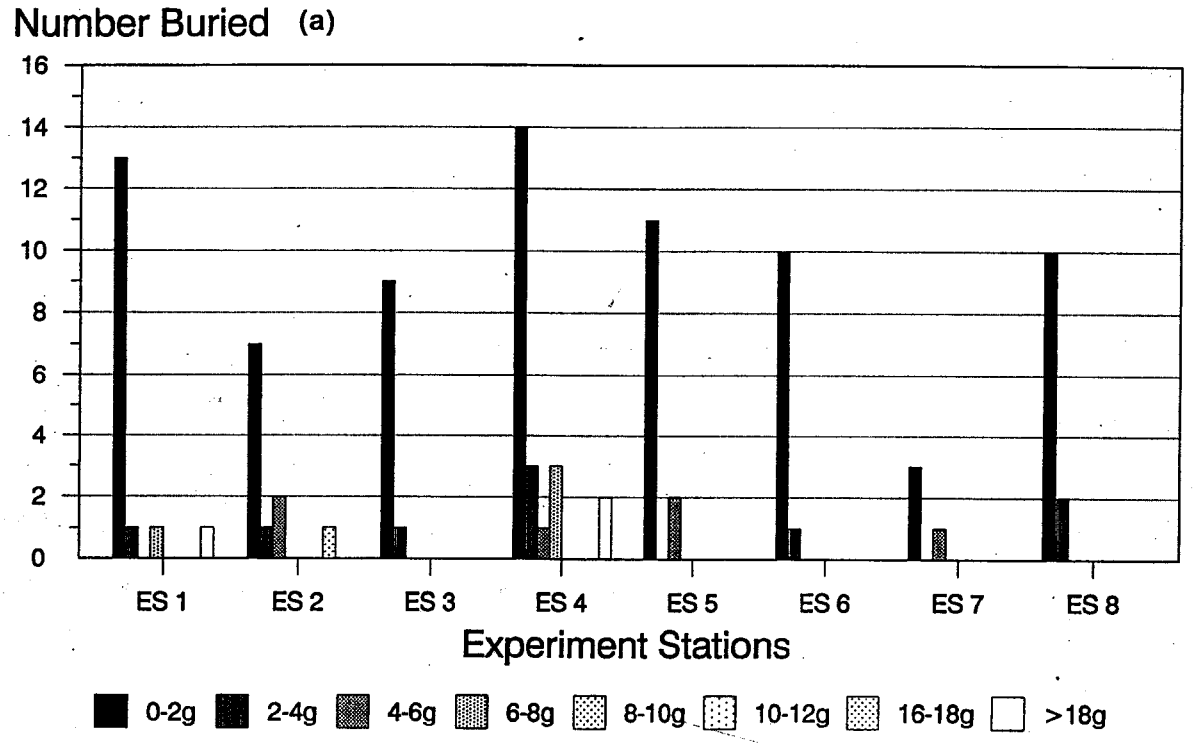


Figure 141. Exposure according to artifact size; (a) items found buried for at least one observation; (b) items found buried at final observation.



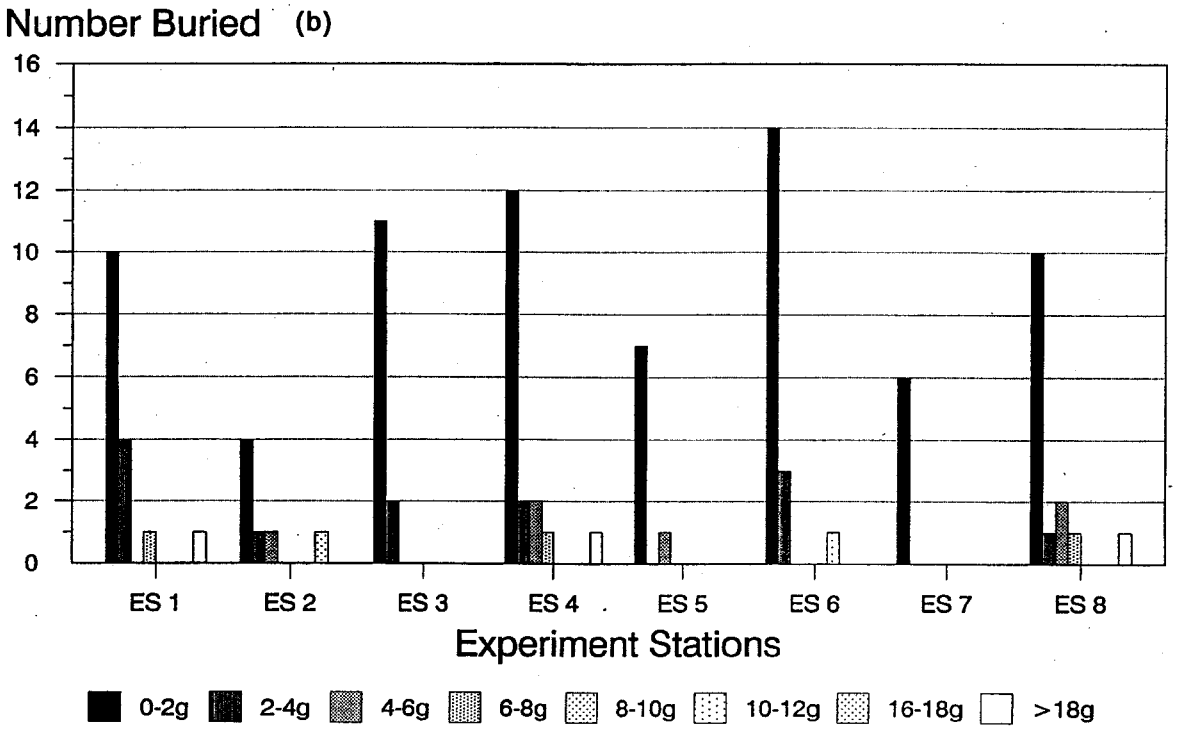


Figure 142. Exposure according to artifact weight; (a) items found buried for at least one observation; (b) items found buried at final observation.

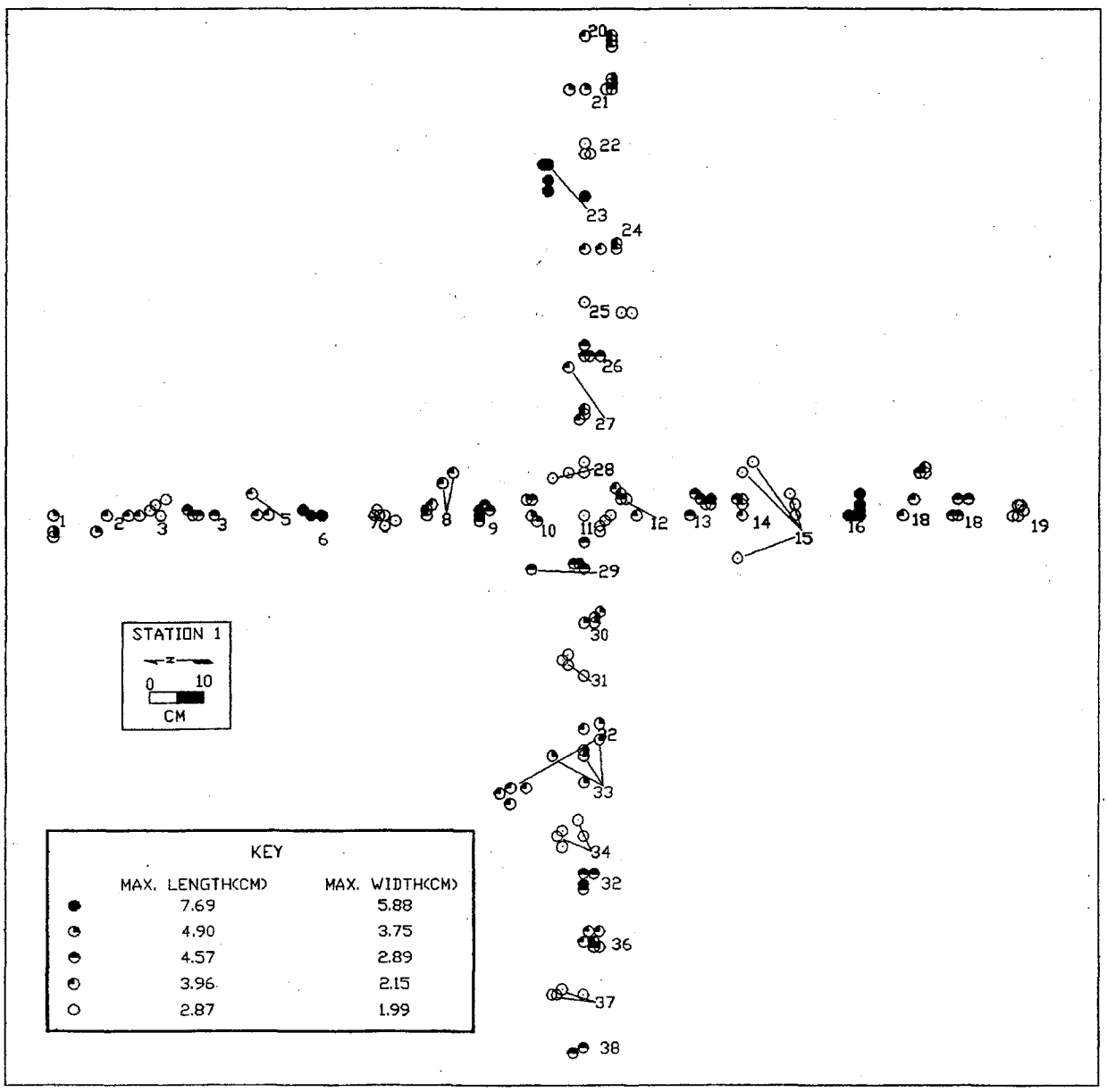
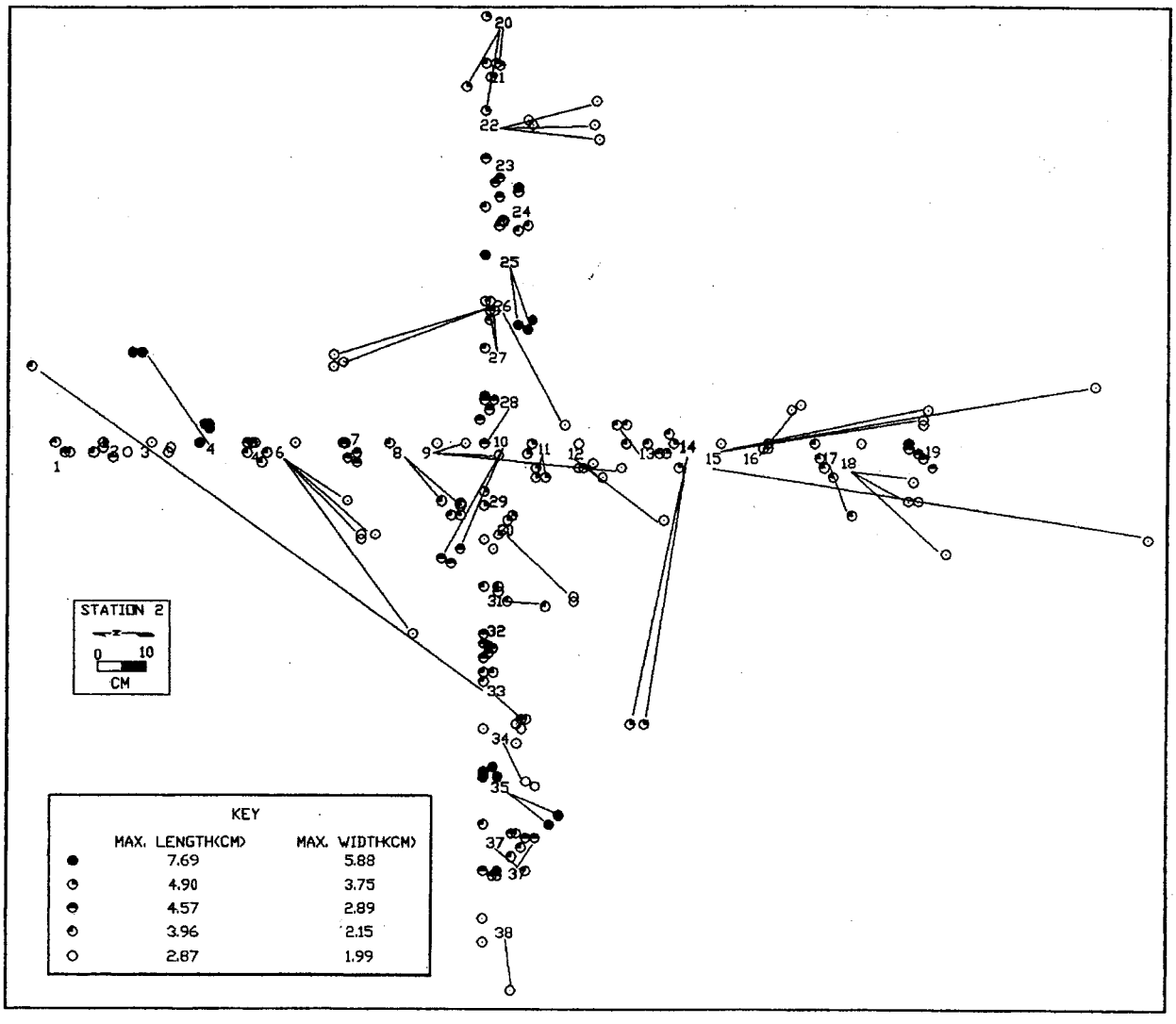


Figure 143. Artifact movement at Experimental Stations 1 and 2 for the duration of the study.



Continuation of Figure 143.

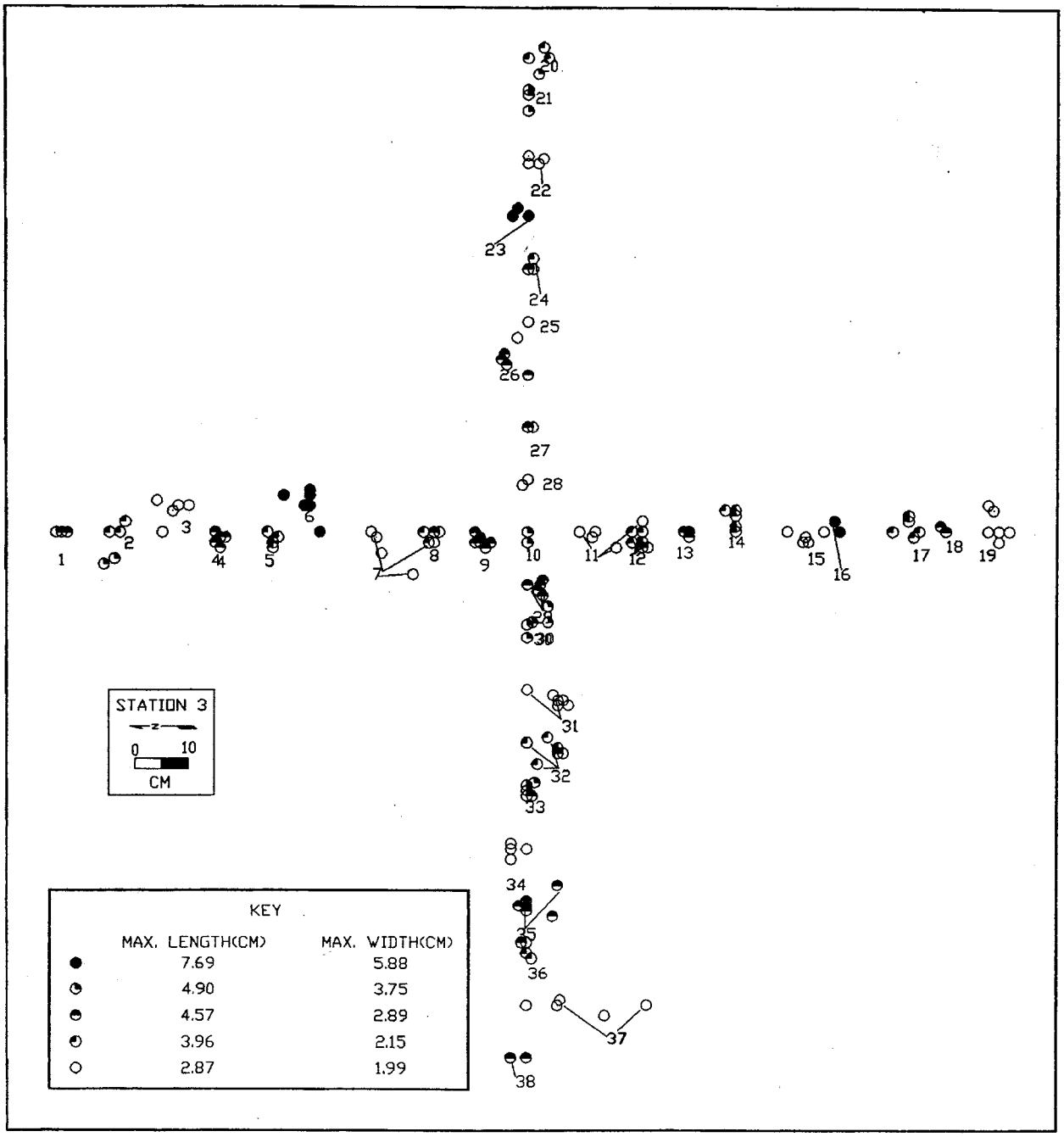
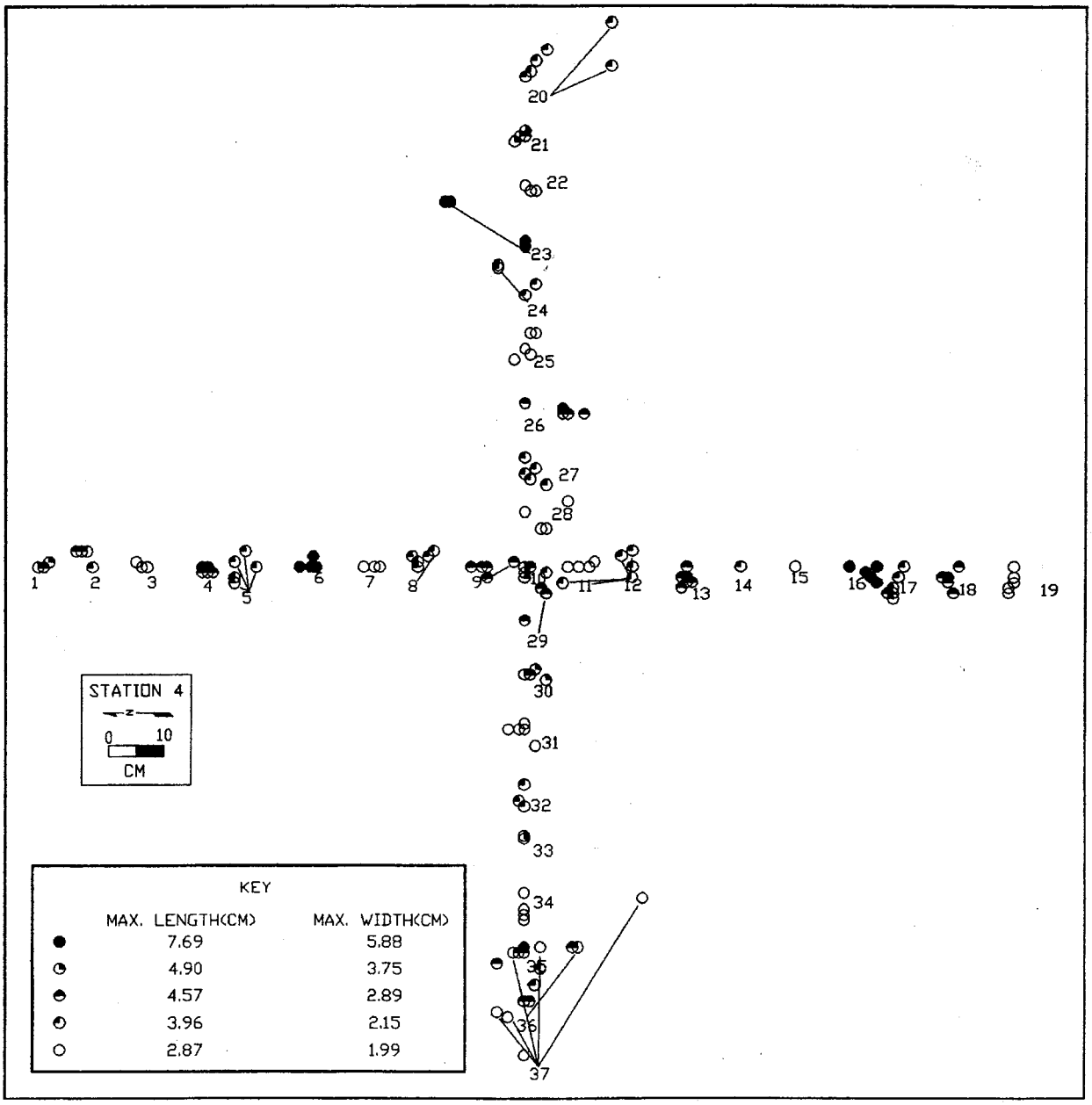


Figure 144. Artifact movement at Experimental Stations 3 and 4 for the duration of the experiment.



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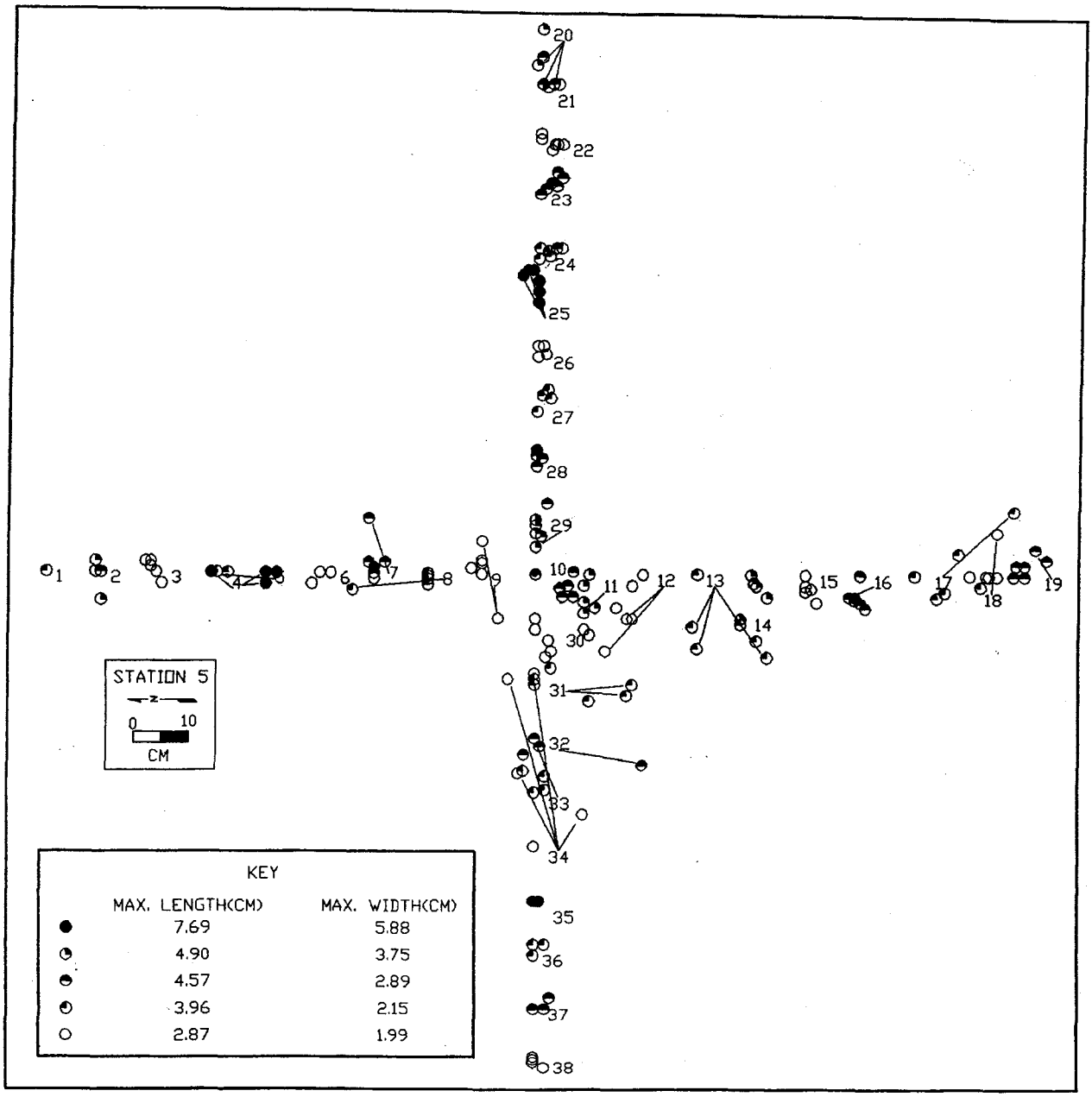
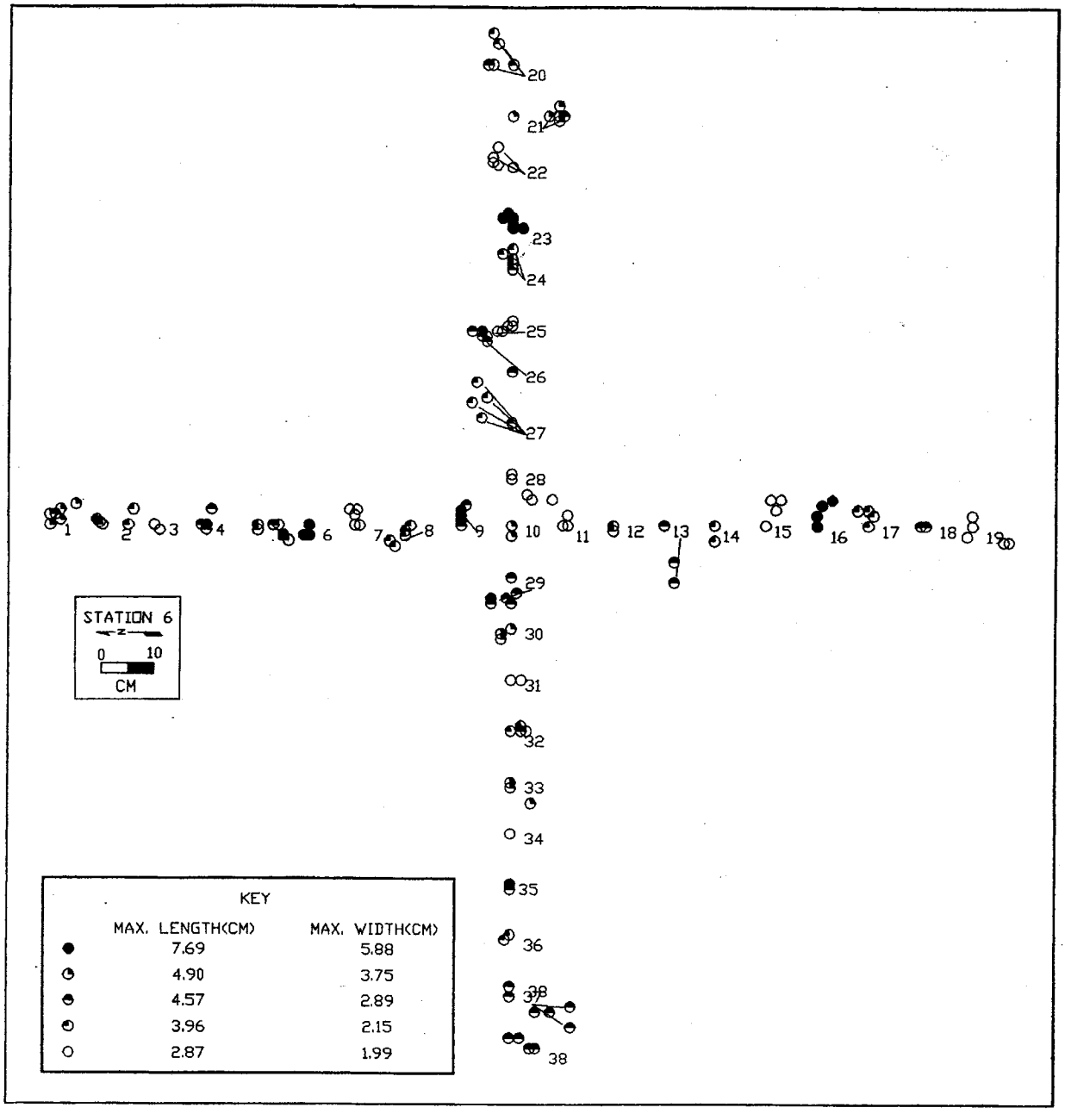


Figure 145. Artifact movement at Experimental Stations 5 and 6 for the duration of the experiment.



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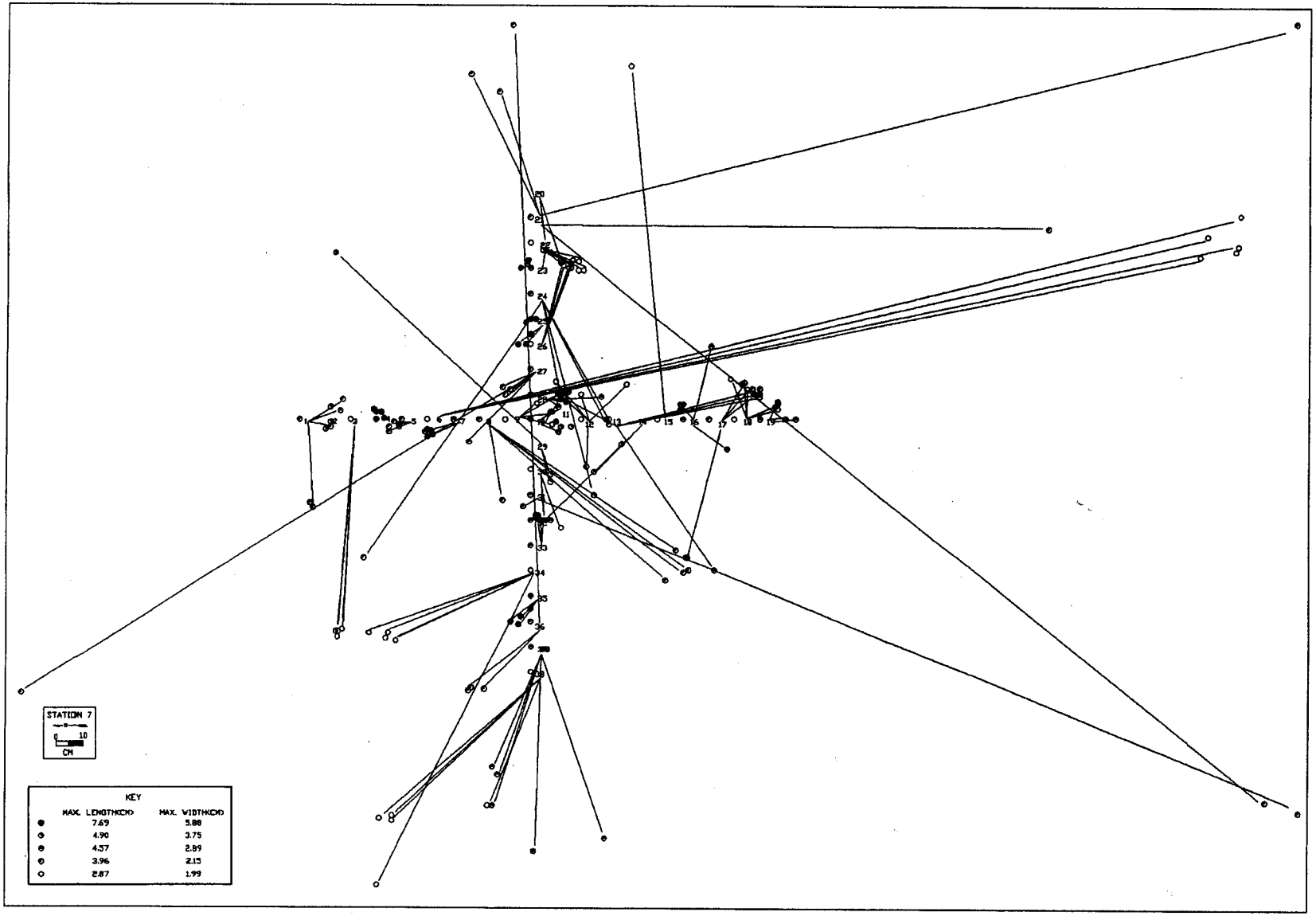
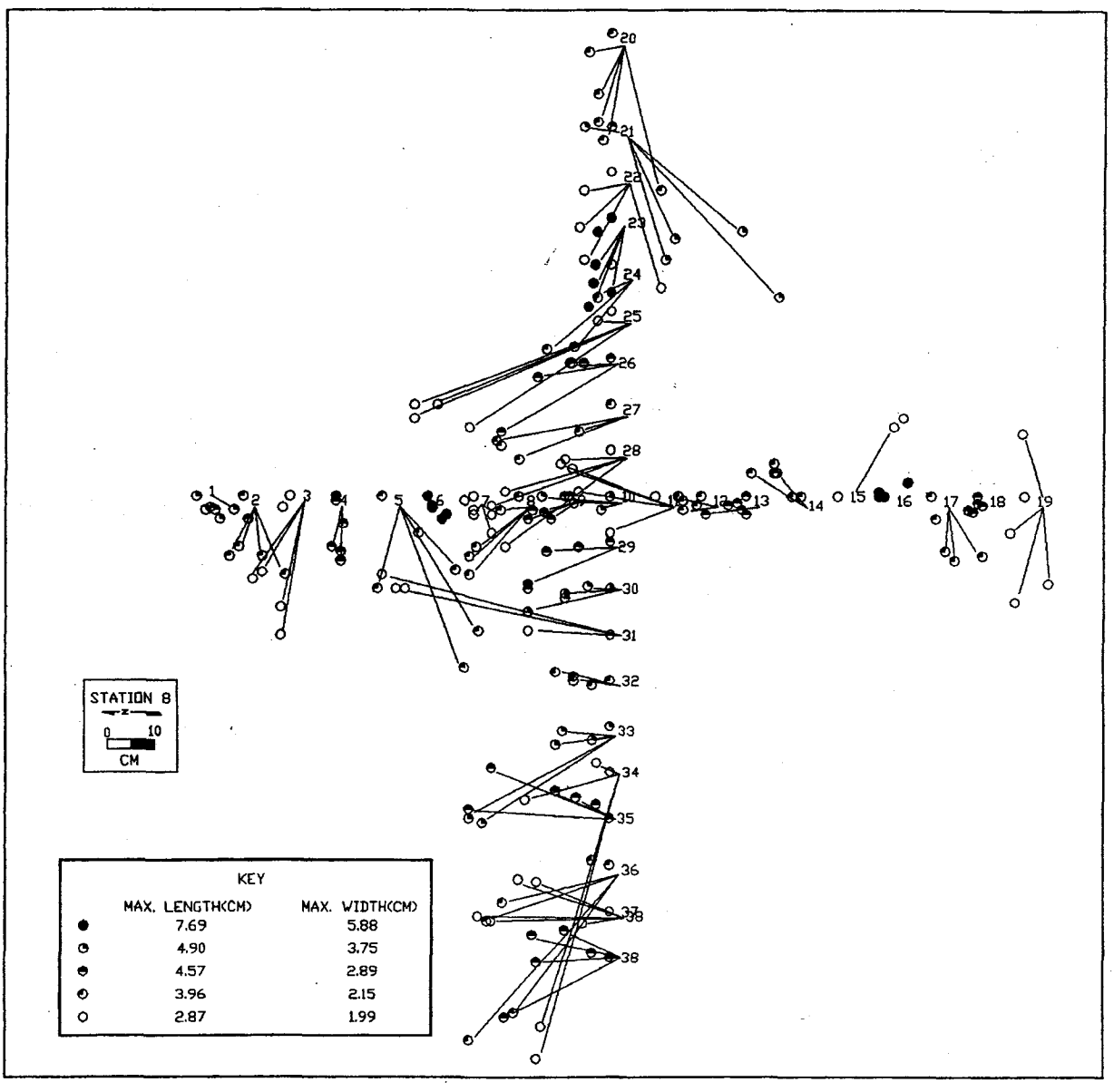


Figure 146. Artifact movement at Experimental Stations 7 and 8 for the duration of the experiment.



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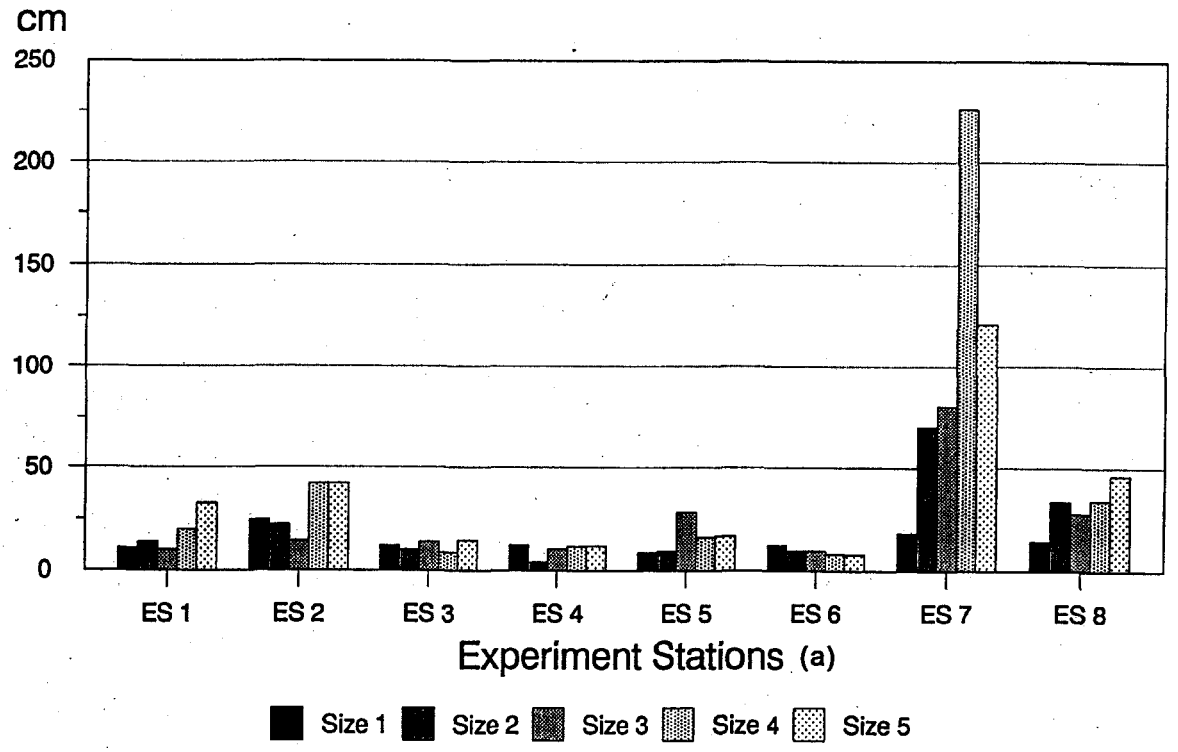

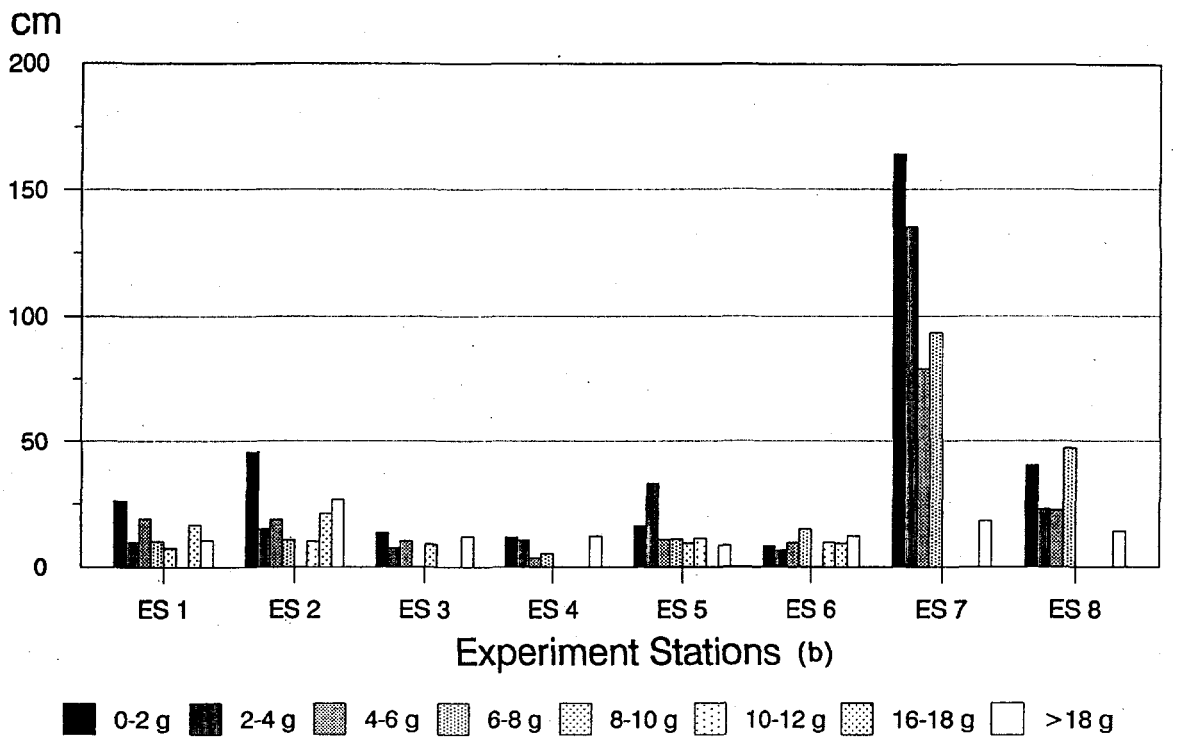

Figure 147. Mean distance moved: (a) according to artifact size for all periods; (b) according to artifact weight for all periods.

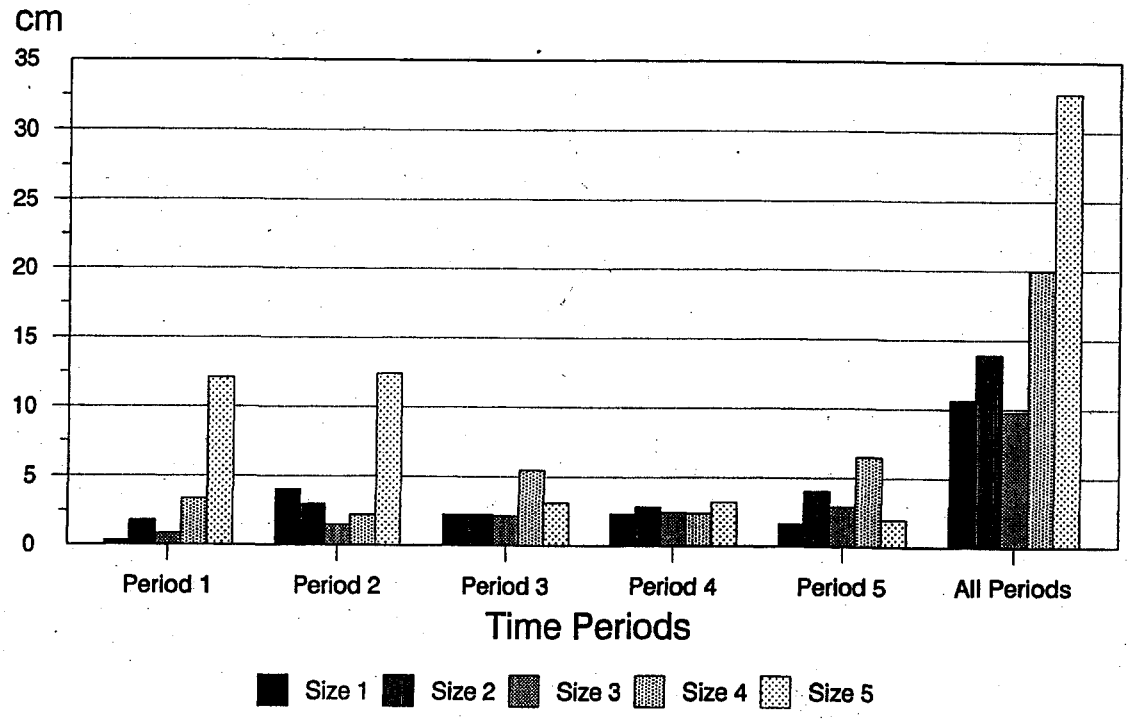

Figure 148. Mean distance moved according to artifact size for Experimental Station 1.

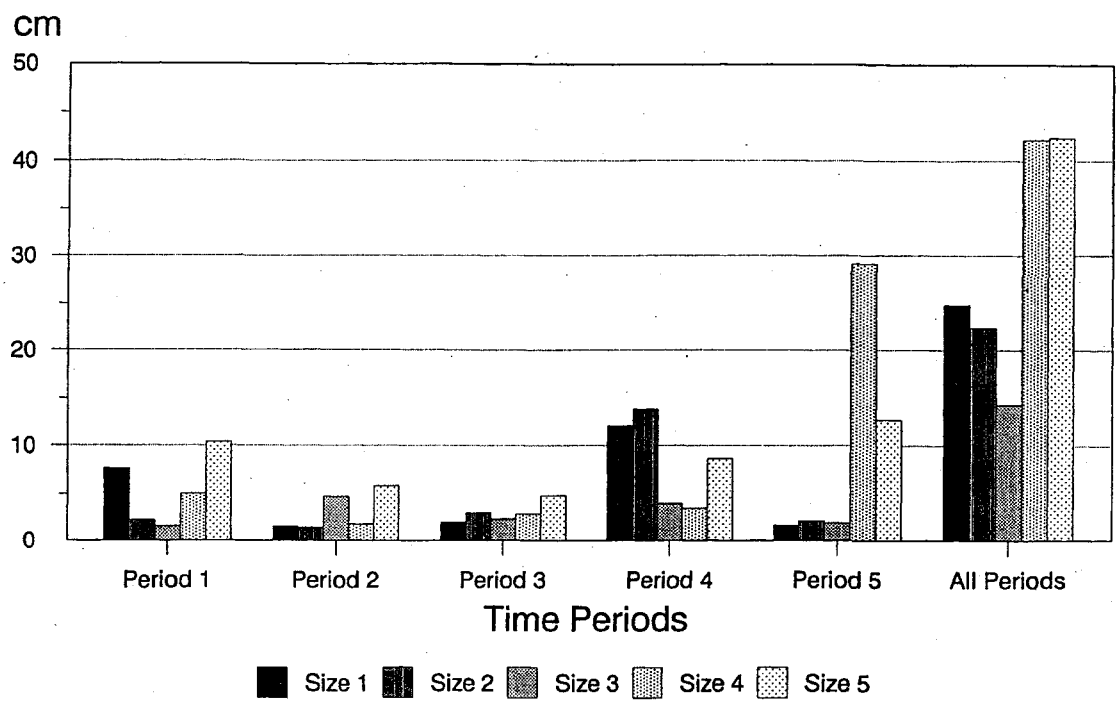

Figure 149. Mean distance moved according to artifact size for Experimental Station 2.

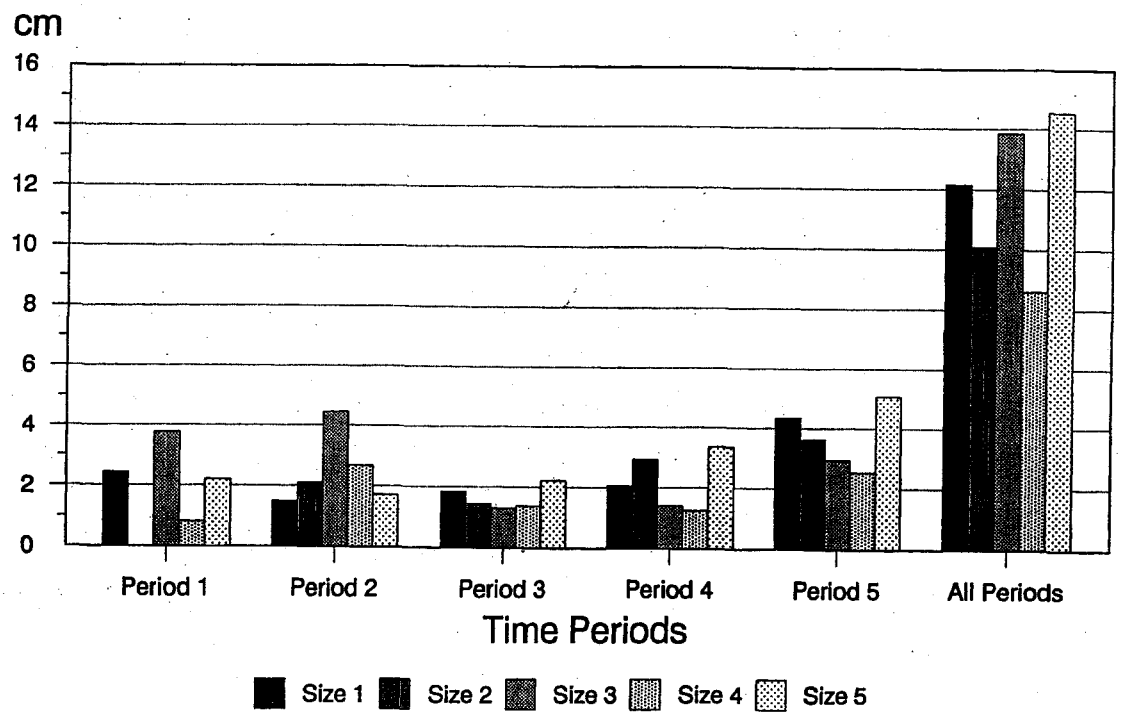

Figure 150. Mean distance moved according to artifact size for Experimental Station 3.

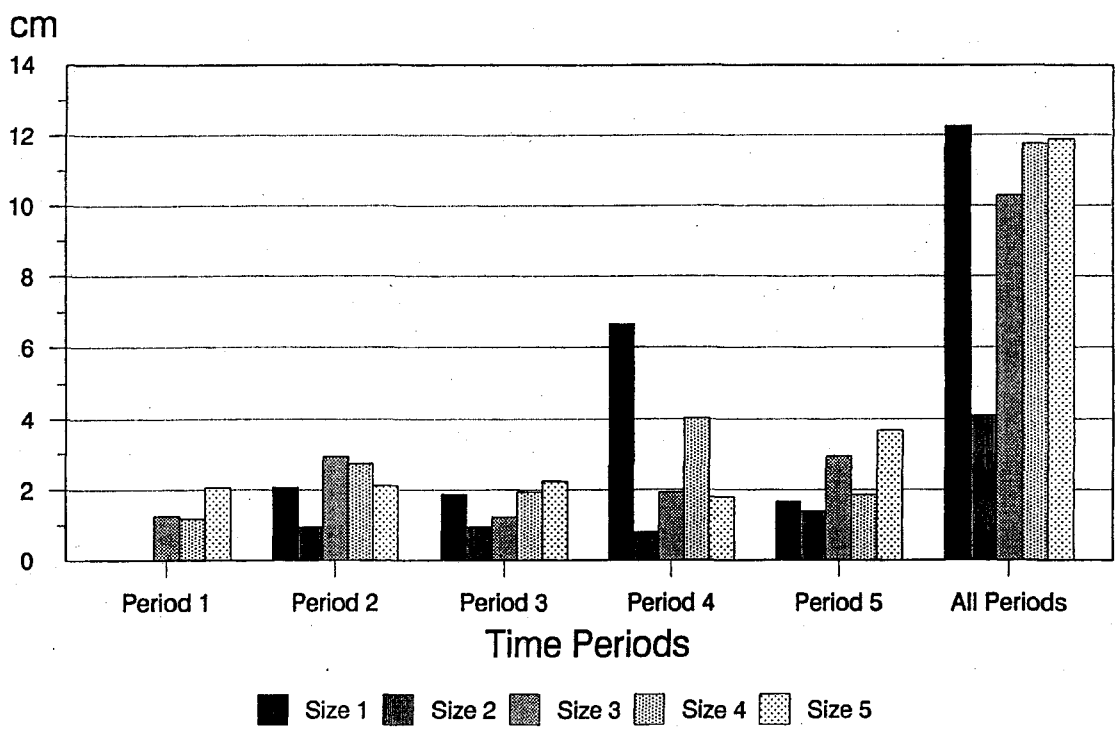

Figure 151. Mean distance moved according to artifact size for Experimental Station 4.

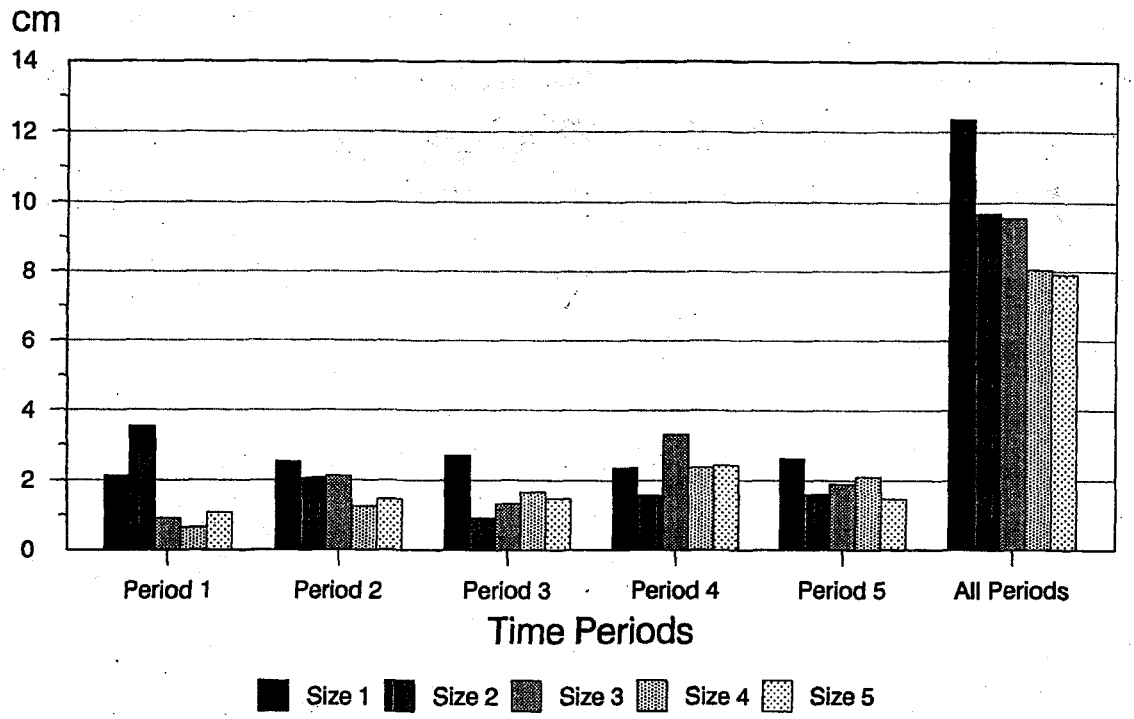

Figure 152. Mean distance moved according to artifact size for Experimental Station 5.

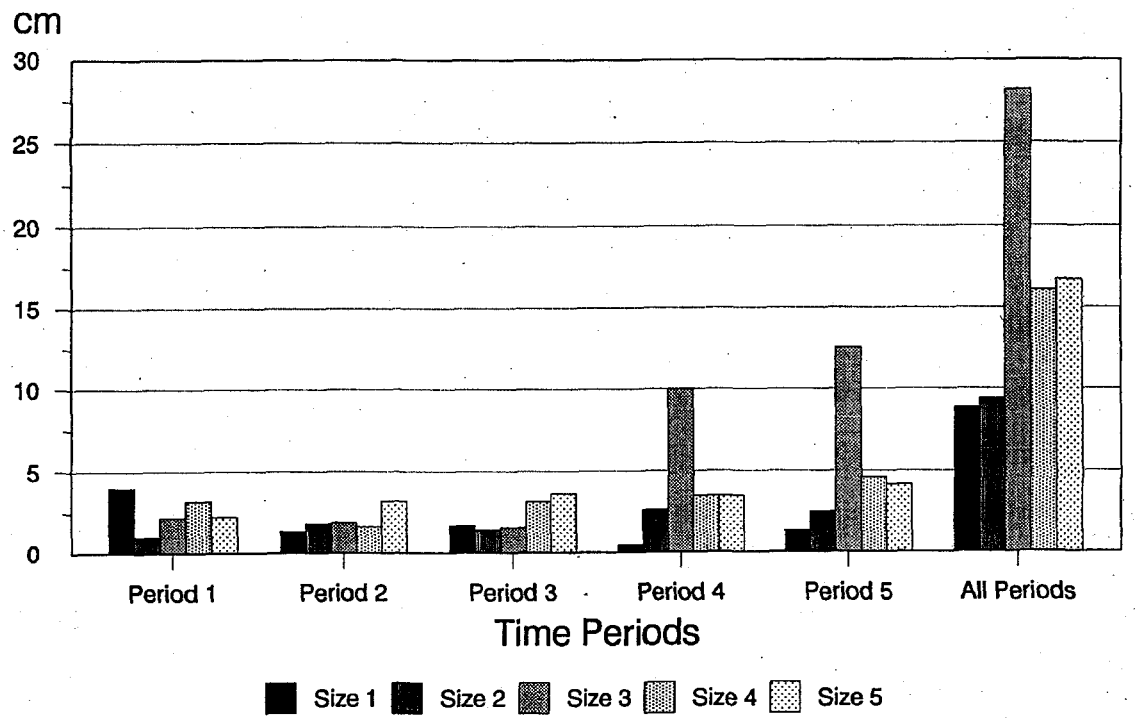

Figure 153. Mean distance moved according to artifact size for Experimental Station 6.

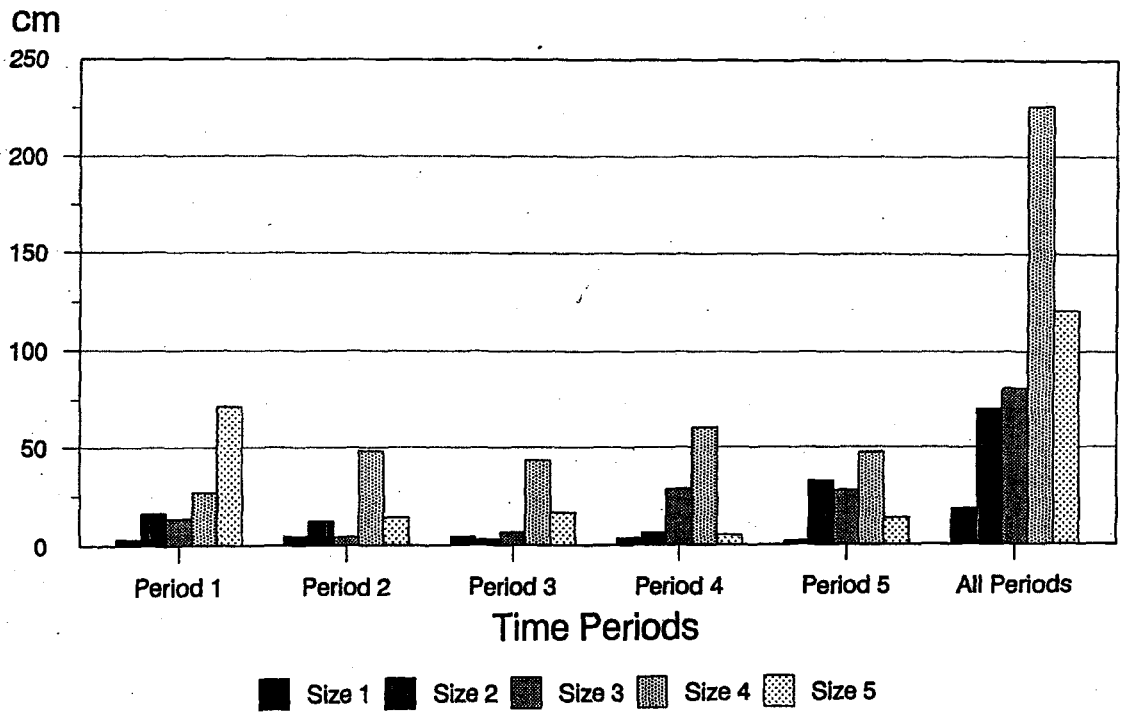

Figure 154. Mean distance moved according to artifact size for Experimental Station 7.

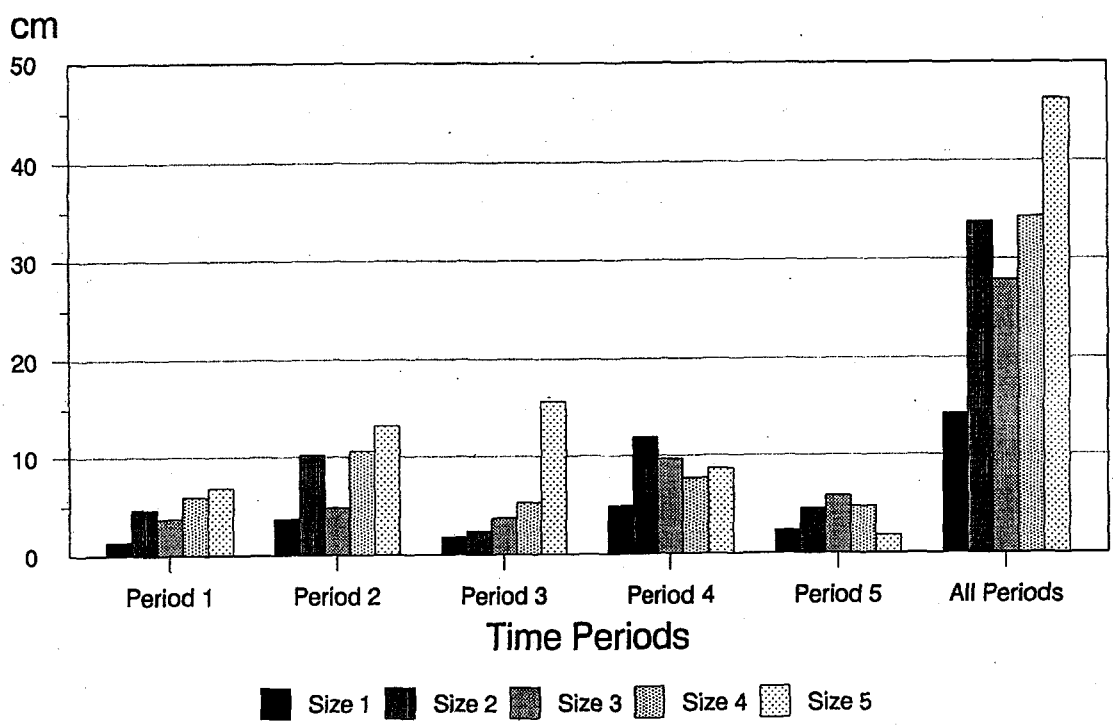

Figure 155. Mean distance moved according to artifact size for Experimental Station 8.

CONCLUSIONS

Southeastern Utah lies within the vast "rain shadow" created along the leeward side of north-to-south trending, parallel mountain ranges in California, Nevada, and central Utah. Sandwiched between the Great Basin and Colorado Plateau provinces, the Canyonlands region can be generally characterized as a cold desert zone. Vast portions of this region consist primarily of solid bedrock, slickrock, and/or sand dunes, where limited and sporadic rainfall provides little support for plant and animal life. Paradoxically, the very dramatic landscape of this arid region, which is characterized by deep, narrow gorges and canyons and spectacular sandstone arches, columns, and spires, has been shaped primarily by water. Furthermore, high plateaus, questas, and isolated mountain ranges create "moisture islands" that punctuate the cold desert landscape. These highland areas bordering Canyonlands attain altitudes of greater than 3,500 meters (amsl) and support alpine meadows and forests of fir, spruce, pine, and aspen.

This seemingly hostile environment contains an extremely rich prehistoric record which spans more than 10,000 years of human occupation. For some investigators, such a rich prehistoric record, including masonry dwellings, cave and rockshelter deposits, storage cists, slab-lined pits, quarries, campsites, and rock art (i.e., petroglyphs and pictographs), would indicate burgeoning populations and optimal living conditions. Yet, this incredibly rich and varied archeological record may actually reflect a variety of prehistoric adaptive responses to a rather high risk and costly set of environmental constraints.

The initial research goals for the Island-in-the-Sky road project included an examination of prehistoric land use patterns; food storage strategies; rock art function; and diet, nutrition, and health interrelationships. These research problems were selected on the basis of their general applicability to the diverse archeological record of southeastern Utah and their broader implications for contemporary archeology and anthropology. Furthermore, these four problem areas were thought to provide a meaningful framework for interpreting the archeological remains within Canyonlands National Park and surrounding federal lands. As mentioned, these problem areas were all explored within the context of investigations on the Island-in-the-Sky; or in related cooperative projects with the Midwest Archeological Center, National Park Service; and in graduate theses and a dissertation.

Archeological survey and mapping techniques were developed for this project as responses to the early development of "off-site" or "distributional archeology." Although a number of large-scale archeological survey and excavation programs have been carried out in the American Southwest, the Island-in-the-Sky project was among the first to implement provenience plotting for all surface artifacts. More than 81,000 surface artifacts within 497 hectares were recorded and systematically tied into both a project-specific and a state-level coordinate system. This data recovery methodology proved invaluable for the spatial analysis of artifact assemblage diversity. And, much information remains for future analyses. This information spans the entire road corridor that measured 100 meters wide and 42 kilometers long.

More than 600 test excavations revealed subsurface deposits and features at nine locations along the road corridor. Most of the excavations were conducted at two locations—the Gray's Pasture site (42SA16858) and the Dunes site (42SA8506). The Gray's Pasture site (42SA16858) may be a field camp where ceramic vessels and ground stone implements were cached. Food getting and processing were carried out at fixed points where prepared hearths, slab-lined pits, and cache pits were constructed. These could have involved parching and wet grinding grass seeds and the preparation of "damper," like that prepared by Australian Aborigines discussed in the ground stone section of this report. As pointed out previously, the appearance of grinding stones for processing grass seeds in the archeological record suggests that considerable effort was devoted to plant processing, and these handling costs were quite high. Pollen washes of ground stone specimens revealed that a variety of wild plants, including *Amaranthus*, *Atriplex*, *Chenopodium* *Cleome*, *Ephedra*, *Plantago*, *Opuntia*, *Shepherdia*, and *Typha*, were processed with these implements.

A taphonomic study of the unidentifiable bone fragments revealed a range of depositional environments for the excavated faunal assemblages. This line of investigation also offered insights into the nature of site history—specifically the number of episodes of site reuse. For example, faunal materials recovered from the Neck site (42SA8502) suggest that there were two periods of site use; one occupation or use episode appeared at 40-60 cm below the present ground surface and a second occurred between 0-15 cm. Bone exhibiting varying stages of weathering appeared mixed and suggested that the site's surface was not stable during deposition due to deflation and/or other disturbances. On the other hand, faunal remains from 42GR913 exhibited Stage 1 weathering and appear to have been rapidly buried in deposits between 65-105 cm below the present ground surface. The analysis also indicates that there were at least two occupational events or use episodes at the Gray's Pasture site (42SA16858), where hearths, shallow pits, metates and manos, and a large recycled Mesa Verde Black-on-white olla were recovered during excavations. These insights into land surface stability, depositional conditions, and numbers of use episodes are very useful in gaining a better understanding of archeological locations like Gray's Pasture (42SA16858).

The pit features, charred logs, charcoal stains, unmodified sandstone slabs, burned rock, ceramic vessels, faunal remains, and the human burial recovered at the Dunes site (42SA8506) suggest that a prehistoric pithouse had been constructed within deep sand dunes at the south end of Gray's Pasture. This "blurred" cluster of features (Features 32-39) exhibited characteristics similar to pithouses excavated elsewhere in southeastern Utah. Deep, homogeneous sand dune deposits and possible road construction activities contributed to the difficult field interpretation of this set of features at 42SA8506. Three radiocarbon dates were obtained from this location; they range from A.D. 585-900 to A.D. 895-1195. These features quite possibly represented a pithouse structure like those illustrated by Lister et al. (1960:107-119, Figures 32 , 33, 36, 37) at Coombs Village near Boulder, Utah. These two pithouses (Structures P and R) were constructed in pits about 3-4 meters in diameter and between 1 to 1.5 meters deep. Pithouses have been observed in this area along low terraces bordering the Colorado River to the east and Seven Mile Canyon to the north (Davis et al. 1989; Pierson 1981). Such pithouses were probably utilized during winters that were not conducive to ungulate exploitation in the nearby mountains, i.e., the La Sal, Abajo, and Henry ranges.

Cameron (1990) has recently reviewed archeological data concerning site history and pithouse abandonment in the American Southwest. Forty-four of the 88 pithouse cases that she examined had burned, and 40 percent contained restorable ceramic vessels on the floor. Less than 10 percent of these pithouse structures contained human burials. She (1990:35) states that, "Ethnographic evidence suggests that burning might be the result of ritual activities, such as the burning of a house after the death of the owner or as a response to insect infestation."

Logistical locations like the Gray's Pasture site (42SA16858) on the Island-in-the-Sky were perhaps associated with summer use of more extensive home ranges. Prehistoric groups, like the historic Southern and Northern Paiute, probably expanded their range to cover more than 10,000 square kilometers—an area equivalent to a circle with a diameter of 112 kilometers (70 miles). We might expect that such home range requirements would be even more extensive if large portions of this area were barren slickrock like that within the Canyonlands region. During the growing season, locations on the Island were visited, and plant resources were procured and placed in storage. Small masonry structures known as "granaries" were used for this purpose.

Forty-eight archeological features were examined during the course of fieldwork. Twenty-six charcoal and ash stains made up more than 50 percent of these features, while hearths and slab-lined pits represented 27 and 10 percent, respectively. Radiometric determinations based on wood charcoal recovered from these archeological features range in age from +2740 to +120 radiocarbon years, or from 1095-790 B.C. to A.D. 1655-1950. Slab-lined pits excavated on the Island-in-the-Sky yielded dates ranging from 1095-790 B.C. to A.D. 65-430 along Murphy Trail.

Initially, we had hoped that more human bone samples from the Island-in-the-Sky would be available for stable isotope analysis. Samples of human osteological material were later collected from two existing collections in southeastern Utah in order to gain a better understanding of prehistoric diet composition. Bone chemistry research has become quite sophisticated since the original research program was written in 1984. The

ecological and chemical basis for this approach to dietary studies has been discussed in considerable detail elsewhere. Readers should consult these sources for background information (e.g., DeNiro 1987; Price et al. 1985; van der Merwe 1982).

Results of the stable carbon (^{13}C) and nitrogen (^{15}N) analyses are presented in Appendix B. The ^{13}C value, based on gelatin derived from the human burial from the Dunes site, (42SA8506) equals -8.9 ‰. The mean ^{13}C value for present-day C_4 plants equals -12.5 ‰ (range -16.0 to -9 ‰). If these values are corrected for the elevated levels of CO_2 in the current atmosphere due to combustion of fossil fuels, these ^{13}C values are -11.5 ‰ (mean) and -15.0 to -8.0 ‰ (range). In turn, these plant values must be corrected for enrichment during metabolism and bone formation that equals +5.1 ‰. Mean bone collagen values of ^{13}C reflecting a C_4 plant diet then equal -9.9 ‰ to -2.9 ‰. The Dunes site collagen value for ^{13}C lies within this range for C_4 plant-based diet.

Fourteen additional samples of human bone from southeastern Utah yielded ^{13}C values based on collagen that lie within this C_4 dietary range. Typically, similar ^{13}C values have been interpreted as evidence for a maize-based diet (e.g., Decker and Thiezen 1989). Such an interpretation is complicated by three additional factors in southeastern Utah: (1) consumption of C_4 plants other than maize, e.g., amaranth; (2) consumption of plants that use Crassulacean acid metabolism (CAM); and (3) consumption of animals that consume C_4 and/or CAM plants.

In this study, stable nitrogen isotopes ($^{15}N/^{14}N$) suggest that animals as well as plants are responsible for a number of the observed human bone collagen values in southeastern Utah. Once these values are corrected for collagen enrichment, they place the samples within a bivariate plot (^{13}C vs. ^{15}N) that suggests a human diet derived from C_4/CAM-dependent herbivores. Four individuals exhibit stable ^{13}C and ^{15}N which suggests a C_4/CAM diet. These individuals were recovered from 42SA18513, Nielson Effigy (1); Polley-Secrest (1); 42SA6396 (1); and Squaw Point, ECPR (1). Eight individuals exhibit stable isotope values that suggest C_3 plant diets; they were recovered from 42SA8506, Dunes (1); Polley-Secrest (4); 42SA6391, White Mesa (1); Squaw Point, ECPR (1); and 42SA700, Edge-of-the-Cedars (1). One individual ("Basketmaker affiliation") exhibits isotope values that suggest a plant-based diet dominated by C_4/CAM plants. Research conducted in Canyonlands indicates that prehistoric diets were diverse. Palynological, macrobotanical, faunal, and chemical data suggest that maize was a component of the human diet at least during the Anasazi occupation(s). A variety of wild plants were consumed; however, it appears that plant food resources were predominantly C_4 or CAM plants. Furthermore, higher ^{15}N values suggest relatively high reliance on C_4-dependent herbivores.

In winter, the same aboriginal groups aggregated in the uplands, or the "moisture islands," and hunted resident herds of ungulates, including mule deer, elk, and bighorn sheep. This land use model based on ungulate exploitation and use of the uplands as an integral component of the overwintering strategy differs markedly from traditionally held views regarding prehistoric life on the Colorado Plateau. We have presented it here in order to provide a broader interpretative framework, within which the archeological record of the Canyonlands region can be viewed. Given this model, we should not expect to observe much evidence for the prehistoric use of the Island-in-the-Sky area as an overwintering location.

Faunal remains recovered from the excavated sites in this study included 15 genera and 5 general categories of small to large mammals. The fifteen genera included small mammals, e.g., *Lepus* (jack rabbit), *Sylvilagus* (cottontail), *Spermophilus* sp. (ground squirrel), *Dipodomys* sp. (kangaroo rat), *Neotoma* sp. (wood rat), *Cynomys* sp. (prairie dog), and *Thomomys* sp. (northern pocket gopher), as well as medium to large mammals, e.g., *Ovis canadensis* (bighorn sheep), *Antilocapra americana* (pronghorn antelope), *Odocoileus hemionus* (mule deer), *Bison bison* (bison), and *Ovis aries* (domestic sheep). Sorenson's (1948) quotient of species similarity was used to compare the faunal assemblages from the excavated sites in the study area with sites from Black Mesa, Arizona, and the Dolores River area of southwestern Colorado. These archeological faunal assemblages had been classified by other investigators as residential loci, special-purpose loci with structures, and special-purpose loci without structures. These comparisons, based on similar combinations of species, exhibit considerable variation. They generally appear to represent short-term, limited-activity locations with variable site histories. Activities conducted at these locations most probably involved hunting and processing of small and large mammals (e.g., 42SA8502), as well

as the processing of bone marrow and/or grease (e.g., 42SA8502 and 42SA8506).

Additional insights into aboriginal land use tactics were provided by the preliminary analysis of the lithic debitage collected within several gridded transects at the White Crack site (42SA17597). Prehistoric hunter-gatherers procured high-quality chert from an exposed stratum beneath the White Rim. This raw material was then shaped into bifacial cores and transported to numerous locations, including the Island-in-the-Sky. This mode of lithic procurement, processing, and transport reflects hunter-gatherer adaptation(s) characterized by high residential mobility in regions where suitable raw materials are not ubiquitous or uniformly distributed (Parry and Kelly 1987). Such groups manufactured formal flaked stone tools and used a standardized core technology. Bifacial cores and formal tools ".. can be resharpened and reused repeatedly for the same task" (Parry and Kelly 1987:298). As mentioned, a number of the artifact scatters examined during this study produced lithic assemblages dominated by debitage, i.e., interior flakes, biface thinning flakes, and pressure flakes, indicative of such resharpening and reuse episodes. Based on one radiocarbon date from the White Crack site (42SA17597), we can say that such activities occurred at least during the period circa 1400-925 B.C. Lithic assemblages dominated by reuse and resharpening debris were recorded for sites 42GR2025, 42SA8500, and 42SA8512 that yielded radiocarbon dates ranging between 2740 (1095-790 B.C.) and 120 (A.D. 1655-1950). Although these assemblages have been combined for analysis and their direct association with the dated features cannot be confirmed, the data suggest that aboriginal groups remained highly mobile in this region until quite late in the prehistoric period.

The analysis of archeological assemblage diversity and spatial scale suggests that stone tools actually represented a very small component of prehistoric technology. The very redundant character of the assemblages at varying spatial scales within two large lithic scatters at Alcove Spring (42SA8512) and at Murphy Point (42SA8500) supports this argument. Interior flakes, biface thinning flakes, and pressure flakes dominate these assemblages. Bifacial cores were prepared near quarry locations and were transported to the Island and surrounding locations. These bifacial cores were then thinned and the resulting flakes were utilized for the manufacture of other implements and facilities, including digging sticks, throwing sticks, atlatls, darts, arrows, bows, baskets, carrying bags, hides, and nets.

The experimental work conducted on the Island-in-the-Sky regarding artifact displacement provided two significant in sights. First, the smaller artifacts exposed on various substrates in this area are mobile. As a result, smaller items and frequently the artifact categories they represent, will be underrepresented in surface assemblages. Second, the spatial distribution of artifacts on the surface is modified by natural processes; however, such blurring or displacement occurs at a spatial scale smaller than one or one-half square meter. Given these results, we can argue more effectively about the spatial integrity of the artifact scatters and analyses of spatial distribution related to past human behavior.

This research is designed to integrate current knowledge, to answer pertinent questions, and to generate new directions for future investigations. We believe that our efforts have been successful. First, our focus on prehistoric land use strategies required that we develop a means for assessing the significance of artifact scatters; frequently such archeological locations were ignored or were considered of limited scientific value. These surface artifact scatters were studied with respect to assemblage pattern diversity. This approach enabled us to examine site structure at variable spatial scales. Such an approach could most certainly be applied to large block excavations as well. This aspect of our research should be the focus of future archeological investigations.

Second, our analysis of the flaked stone assemblages revealed that more than 99 percent consisted of debitage categories, including interior, biface thinning, and pressure flakes. We suggest that bifacial cores were transported to sites on the Island at which flakes were produced and formal tools were sharpened. Future research should re-examine these debitage categories in order to assess these conclusions further. We also propose that perhaps many of these flake tools were used to produce other tools manufactured from a range of organic materials.

Third, the land use model based on ungulate hunting leads us to expect that the nearby mountain ranges should contain a number of archeological sites that reflect prehistoric overwintering adaptations. The characteristics of such locations are briefly discussed in

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APPENDIX A

DOCUMENTED FIELD INVESTIGATIONS IN THE ISLAND-IN-THE-SKY DISTRICT, CANYONLANDS NATIONAL PARK

Date	Investigator	Location and Work Accomplished
1950	W. Claflin R. Emerson	Expedition down the Green River. Fort Bottom River 42SA78 (42SA423) was described (Gunnerson 1969; Morss 1931).
1951	J. Rudy	Trip down the Green and Colorado Rivers where at least five sites on the rivers were located, some believed to be along Bonito Bend and a few in the Maze District (Rudy 1952:4-9).
1958	J. Gunnerson	Survey of Dead Horse Point and Junction Butte areas. Sixteen sites discovered, ten of which are in Island-in-the-Sky District (Gunnerson 1958).
1965-1966	F. Sharrock	Inventory of areas considered to be accessible in the Island-in-the-Sky District (Sharrock 1966).
1973	L. Lindsay R. Madsen	Six sites discovered in Island-in-the-Sky District while surveying the proposed right-of-way for the Grandview Point road from Utah State Highway 160 to Grandview Point (Lindsay and Madsen 1973:17-27).
1975	L. Losee W. Lucius	In addition to their survey work in the Maze District, eight sites were reported in the Upheaval Bottom and Fort Bottom areas (Losee and Lucius 1975).
1979	R. Hartley	Discovery of 28 sites primarily along the Island-in-the-Sky road corridor (Hartley 1980).
1983	S. Vetter	Survey, subsurface testing, and mitigation of sites located along the access road to the Island-in-the-Sky District (Phase I) (Calabrese 1984; Thiessen 1984).
1984	S. Vetter	Fenceline survey, north boundary, Island-in-the-Sky District, no sites located (Vetter 1985a).
1984	A. Osborn	Survey of sample transects in Island-in-the-Sky District. Eleven sites recorded (Osborn 1984).

ISLAND-IN-THE-SKY

Date	Investigator	Location and Work Accomplished
1984	S. Vetter	Survey, subsurface testing, and mitigation of sites located along portion of Island-in-the-Sky roadway (Phase I) (Vetter 1985b).
1985	S. Vetter	Survey, subsurface testing, and mitigation of sites located along portion of Island-in-the-Sky roadway (Phase II) (Vetter 1986).
1986	A. Anderson	Reconnaissance survey of area of Green River overlook road. No cultural materials observed (Anderson 1986).
1986	J. Gaunt S. Eininger	Structural stabilization of five sites in the Island-in-the-Sky District (Gaunt and Eininger 1987).
1986	J. Firor S. Eininger	Structural stabilization of four sites and stabilization sites and stabilization assessment of one site along the Green and Colorado Rivers (Firor and Eininger 1987).
1987	S. Vetter	Archeological testing and evaluation of site 42SA17597 near the White Crack Campground on the White Rim (Vetter 1987; Osborn and Vetter 1989; Osborn et al. 1993).
1987	C. Cartwright	Archeological survey of 11 proposed backcountry campsite locations along the White Rim. No previously unrecorded cultural resources were observed (Cartwright 1987).
1988	C. Cartwright	Reconnaissance and intensive survey in the area of existing and proposed employee housing in the Island-in-the-Sky District. No cultural resources were observed in the previously disturbed or undisturbed areas (Cartwright 1988).

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APPENDIX B

HUMAN OSTEOLOGICAL REMAINS
DUNES SITE (42SA8506)

Unit	FS	Count	Element	Side
97	302	1	Ulna/radius fragment	right
97	295	1	Ulna/radius fragment	right
97	332	1	Clavicle, complete	left
97	343	1	Metatarsal, complete	left
97	248	1	Metatarsal, diaphysis	----
97	362	1	Phalanx, complete	left
97	230	1	Mandible, fragment	left
97	172	1	Axis, complete	----
97	102	1	Baso-occipital fragment	----
97	173	1	Ischium, fragment	----
97	347	1	Pelvic fragment	----
97	348	1	Cuneiform	left
97	304	1	Ilial crest fragment	----
97	103	1	Cranial frag., styloid?	----
97	243	1	Cervical vert., complete	----
97	380	1	Radius, dist./medial	right
97	242	1	Cranial fragment	----
97	320	1	Lumbar, artic. process	----
97	286	1	Ilial crest fragment	----
97	268	1	Incisor, extreme attri.	----
97	351	1	Lumbar vertebra, artic. surface	----
108	92	1	Humerus, distal fragment	left
108	97	1	Talus, complete	left
108	49	1	Ulna, proximal half	left
108	50	1	Ulna/radius diaphysis fragment	----
108	57	4	Radius, diaphysis fragment	left
108	77	1	Radius, diaphysis fragment	left
108	105	24	Tibia, diaphysis fragments	left
108	105	1	Tibia, prox. superior surface	left
108	105	1	Tibia, distal	left
108	104	5	Fibula, nearly complete	left
108	99	1	Fibula, distal fragment	left
108	83	1	Phalanx, complete	----
108	96	1	Phalanx, nearly complete	----
108	95	1	Phalanx, missing anterior end	----
108	106	1	Phalanx, nearly complete	----
108	114	2	Phalanges, complete and medial	----
108	89	1	Pelvic fragment	----
108	107	1	Metatarsal	----
108	76	7	Radius, fragment?	----
108	86	4	Metatarsal fragments?	----
108	54	1	Humerus or femur fragment	----
108	93	5	Acetabulum/ischium fragments	----

Unit	FS	Count	Element	Side
108	91	2	Pelvic fragments	----
108	70	1	Scapula or pelvis fragment	----
108	111	1	Pelvic fragment	----
108	90	1	Calcaneus fragment	----
108	110	1	Femur head?	----
108	58	1	Ulna, proximal half	right
108	103	1	Fibula, nearly complete	right
108	84	1	Ulna/radius fragment	----
108	93	1	Femur, medial fragment	----
108	93	8	Femur, distal fragments	----
108	108	1	Tarsal, nearly complete	----
108	120	2	Humerus, distal fragments	----
108	113	1	Calcaneus, fragment?	----
108	98	1	Metatarsal, fragment	----
108	69	1	Long bone diaphysis	----
108	349	1	Ulna, diaphysis fragment	left
108	94	1	Patella, complete	----
108	120	9	Humerus, distal fragment?	----
108	100	1	Pelvic fragment	----
108	109	2	Pelvic fragments	----
108	82	1	Pelvic fragment?	----
109	27	1	Tarsal, complete	----
109	28	1	Ulna, diaphysis fragment	left
109	56	1	Lumbar vertebra (osteophytosis)	----
109	48	1	Lumbar vertebra, near. complete	----
109	58	2	Pelvic fragments	----
109	20	1	Cervical vert., near. complete	----
109	38	1	Vertebral spinour process	----
110	3	1	Molar, 1st? extreme attrition	----
111	17	1	Vertebra, cervical, complete	----
132	31	1	Phalanx, missing anterior end	----
132	20	1	Phalanx, complete	----
167	22	1	Talus, nearly complete	----
184	14	1	Bicuspid? extreme attrition	----
109	*	11	Rib fragments	----
109	18	1	Cranial fragment	----
111	8,9,11	-	Cranial fragments	----
97	**	28	Cranial fragments	----
97	***	11	Rib fragments	----

*FS nos. 12-15, 18, 40, 42, 50-51, 55, 57.
**FS nos. 159, 167-169, 171, 180-182, 188, 198, 203, 215, 222-223, 244, 274, 287, 353.
***FS nos. 325, 338, 345-346, 363, 365, 369, 376, 382.

Fifteen osteological samples were submitted to Geochron Laboratories (Krueger Enterprises, Inc.) for stable carbon (^{13}C) and nitrogen (^{15}N) analysis. These samples represented 13 human individuals and 2 large herbivores (Order Artiodactyla). Human remains were recovered during excavations at the Dunes Site (42SA8506), as well as from museum collections at the Edge-of-the-Cedars Museum in Blanding, Utah (42SA6391, White Mesa, 1 individual; 42SA700, Edge-of-the-Cedars, 1 individual; 42SA6396, 1 individual; 42SA18513, Nielson Effigy Site, 1 individual; Squaw Point, ECPR, 2individuals) and from Dan O'Laurie Museum in Moab, Utah (Courthouse Wash, Arches National Park, 1 individual; Polley\Secrest Site, Moab, Utah, 5 human individuals and 2 large mammal\mule deer). In addition, Anne Wolley Vawser (Midwest Archeological Center, National Park Service, Lincoln, Nebraska) submitted 5 samples to Krueger Enterprises, Inc., for stable ^{13}C analysis. These results are also presented here (indicated by an asterisk). Specific information regarding the analytical procedures for isotopic analysis of archeological bone can be obtained from Krueger Enterprises, Inc., Geochron Laboratories Division. This information is also on file at the Midwest Archeological Center, National Park Service, Lincoln, Nebraska. We must acknowledge the invaluable cooperation and contributions to this analysis of Lloyd Pierson at the Dan O'Laurie Museum in Moab, Utah, and Winston Hurst at the Edge-of-the-Cedars Museum in Blanding, Utah.

Results of Stable Carbon and Nitrogen Isotope Analyses of Archeological Bone Samples from Southeastern Utah.

Site, Krueger Lab No.		^{13}C gelatin	^{15}N gelatin
42SA8506 CCNR-49452	Dunes Site	-8.9	+8.4
42SA6391 CCNR-49446	White Mesa	-7.7	+8.8
42SA700 CCNR-49447	Edge-of-the-Cedars	-7.4	+9.0
42SA6396 CCNR-49448	Unassigned	-8.0	+7.4
42SA18513 CCNR-49449	Nielson Effigy (Burial 1)	-8.1	+7.6
42SA18513* CCNR-47943	Nielson Effigy (Human Effigy Burial)	-7.5	–
42SA14187* CCNR-47942	Westwater Canyon (Burial 1)	-7.8	–
Unassigned CCNR-49438	Courthouse Wash	-11.6	+7.5
Unassigned* CCNR-47944	King's Bottom	-16.2	–

ISLAND -IN-THE-SKY

Site, Krueger Lab No.		^{13}C gelatin	^{15}N gelatin
Unassigned CCNR-49450	Squaw Point (ECPR)	-8.7	+8.4
Unassigned CCNR-49451	Squaw Point (ECPR)	-8.4	+8.0
Unassigned CCNR-49439	Polley-Secrest (Burial 1, West)	-9.4	+8.6
Unassigned CCNR-49440	Polley-Secrest (Burial "Easy")	-7.9	+8.3
Unassigned CCNR-49441	Polley-Secrest (Burial #2, East)	-10.0	+8.3
Unassigned CCNR-49442	Polley-Secrest (Burial "Baker")	-7.1	+8.2
Unassigned CCNR-49443	Polley-Secrest (Burial 14/27)	-8.0	+7.7
Unassigned* CCNR-47631	Polley-Secrest (Burial 7/27)	-7.8	–
Unassigned* CCNR-47632	Polley-Secrest (Burial 9/27)	-7.5	–
Unassigned CCNR-49444	Polley-Secrest (Herbivore)	-18.6	+5.4
Unassigned CCNR-49445	Polley-Secrest (Herbivore)	-17.8	+3.7

APPENDICES C - G

The large quantity of data contained in Appendices C through G prevents full hard-copy reproduction of those appendices within this volume. The last five appendices of this report are available as groups of electronic data files on MS-DOS format 3.5" disks. Disk copies of these files may be obtained by writing to: Director, Midwest Archeological Center, Federal Building Room 474, 100 Centennial Mall North, Lincoln NE 68508-3873. Ask for "Island Disk Appendices 1995" in your written request.

The list below shows each appendix topic with the file names for that appendix. One sample page for each appendix is provided on following pages for the reader's convenience and reference. Code keys for Appendices E and F are also reproduced here. All DBF, FRM, and NDX files were created with dBASE III Plus, Ashton-Tate, 1986.

Appendix C. Flaked Stone Tool Data. Sample page is on page 398. File names are:

DEBITAGE.FRM DEBITAGE.DBF TOOLS.FRM CNYSORTT.DBF

Appendix D. Ground Stone Tool Data. Sample page is on page 399. File names are:

GRDSTONE.FRM GRDSTONE.DBF GROUND2.FRM

Appendix E. Ceramic Data. Sample page is on page 404. Analysis Code List on pages 400-403. File names are:

CERAMICS.FRM CERAMICS.DBF

Appendix F. Faunal Data. Sample page is on page 410. Code List on pages 405-409. File names are:

FAUNCODE.WS4 FAUNA.FRM FAUNA.DBF

Appendix G. Historic Artifact Data. Sample page is on page 411. File names are:

HISTORIC.FRM HISTSORT.DBF HISTSITE.NDX HISTORIC

APPENDIX C
Tools - Island-In-The-Sky

SIDE OF ROAD	SITE NO.	UNIT	FS#	DEPTH	TYPE	FACE	HAFT	B. TYPE	FORM	COM-PLETE	COR-TEX	MAT.	MAX. LGT.	AXIAL	HAFT LGT.	MAX. WIDTH	BASE WIDTH	NECK WIDTH	MAX. THICK.	WEIGHT	COMMENTS
W	913	28	13	999	1	1	1	3	1	2	3	2	36.00	33.50	10.00	17.00	13.90	12.80	3.10	0.80	TANG FRAG
E	8513	42	5	0	1	1	1	3	8	2	3	2	15.00	0.00	0.00	13.20	26.40	0.00	2.90	1.00	TANG
E	8502	45	13	0	1	1	1	3	1	2	3	1	10.50	0.00	0.00	14.65	14.65	8.45	2.50	0.40	DSN BASE
E	8502	46	77	0	1	1	1	3	1	1	3	1	15.50	13.50	3.85	11.00	11.00	7.20	1.80	0.15	DSN TIP & TANG MISSING
E	8502	46	141	0	1	1	1	3	1	1	3	1	12.85	10.00	5.35	11.65	11.65	7.70	2.25	0.30	DSN PORTION TANG MISSING
E	8502	46	160	0	1	1	1	3	8	2	3	1	12.45	0.00	0.00	11.40	0.00	0.00	2.10	0.30	DSN MIDSECTION
W	2025	54	20	999	1	1	1	3	1	1	3	1	12.35	10.70	3.80	9.60	9.50	5.45	1.80	0.30	DSN
E	8502	54	20	999	1	1	1	3	1	1	3	1	22.50	19.50	6.80	14.00	14.00	9.70	2.30	0.60	DSN TANG AND TIP MISSING
W	8513	54	22	0	1	1	1	1	1	1	3	2	23.00	20.60	6.70	14.00	14.00	7.20	2.35	0.50	ONE TANG MISSING
W	8502	60	76	0	1	1	1	3	1	2	3	1	18.40	0.00	0.00	11.40	0.00	8.45	2.35	0.50	DSN TANG & TIP MISSING
W	8502	61	177	0	1	1	1	1	1	1	3	1	23.60	21.50	8.70	10.90	10.20	6.70	2.60	0.50	DSN
W	8502	61	229	0	1	1	1	3	1	2	3	1	12.80	0.00	0.00	10.10	0.00	0.00	2.20	0.40	LATERAL MIDSECTION
W	8502	62	12	0	1	1	1	3	8	2	1	2	10.40	0.00	7.00	12.80	12.80	7.75	2.00	0.20	DSN BASE FRAG
W	8502	62	51	0	1	1	1	3	8	2	3	2	6.10	0.00	0.00	6.80	0.00	0.00	1.50	0.05	DSN TANG FRAG
W	8502	62	86	0	1	1	1	3	1	2	3	2	6.90	0.00	0.00	11.60	0.00	0.00	2.10	0.25	BASE FRAG fits w/62-201W TANG REPAIRED
W	8502	62	97	0	1	1	1	3	8	2	3	2	5.00	0.00	0.00	6.00	0.00	0.00	1.50	0.05	DSN TANG FRAG
W	8502	62	168	0	1	1	1	3	8	2	3	2	15.00	0.00	8.40	10.60	0.00	0.00	2.75	0.40	DSN TANG FRAG
W	8502	62	404	0	1	1	1	1	8	2	3	1	6.60	0.00	0.00	11.30	0.00	7.55	2.70	0.20	DSN TANG FRAG
W	8502	62	417	0	1	1	1	3	4	1	3	2	15.90	15.60	2.00	10.10	6.80	6.60	2.10	0.30	POINT GENERIC
W	8502	62	460	0	1	1	1	1	1	1	3	1	28.50	26.50	6.50	12.70	12.70	5.30	2.00	0.40	DSN BASE
W	8502	62	494	0	1	1	1	3	8	2	3	2	7.50	0.00	0.00	8.00	0.00	0.00	1.70	0.05	DSN TANG FRAG
W	8502	62	552	0	1	1	1	3	8	2	3	1	10.20	0.00	8.00	13.00	13.00	8.00	2.40	0.30	DSN BASE
W	8502	62	554	0	1	1	1	3	8	2	3	2	6.90	0.00	0.00	7.00	0.00	0.00	1.90	0.10	DSN TANG FRAG
W	8502	62	555	0	1	1	1	1	8	2	3	1	7.15	0.00	0.00	12.70	12.70	6.70	2.20	0.20	DSN BASE
W	8502	62	563	0	1	1	1	3	8	2	3	2	9.60	0.00	7.30	12.60	12.60	5.30	1.65	0.20	DSN BASE
W	8502	62	759	0	1	1	1	3	8	2	3	2	13.00	0.00	0.00	7.40	0.00	0.00	1.90	0.20	DSN TANG FRAG
W	8502	62	914	0	1	1	1	3	8	2	3	1	23.60	0.00	11.40	17.00	17.00	9.10	3.60	1.40	BASE FRAG, ONE TANG MISSING
W	8502	62	915	0	1	1	1	3	1	1	3	2	12.00	11.00	4.45	9.20	9.20	4.80	1.60	0.20	DSN TIP MISSING
W	8502	63	6	0	1	1	1	1	1	2	3	1	20.55	18.20	7.80	12.00	0.00	0.00	2.30	0.40	DSN MISSING TANG
W	8502	63	71	0	1	1	1	3	8	2	3	2	14.75	0.00	0.00	7.30	0.00	0.00	2.65	0.20	DSN TANG

APPENDIX D

GROUND STONE - ISLAND-IN-THE-SKY

SIDE OF ROAD	UNIT	SITE #	FEATURE	FS#	DEPTH	TYPE	RAW MAT.	COM-PLETE	EXMO	NOSUR	NASUR	PLAN	XSEC	FORM	MAX. LGTH	MAX. WIDTH	MAX. THICK.	WEIGHT	COMMENTS
E	42	0	0	37	999	3	1	2	1	1	1	1	1	7	2.5	2.0	0.9	5.4	1 of 2 FRAGS
E	42	0	0	37	999	3	1	2	1	1	1	1	1	7	1.5	2.1	1.0	4.2	2 of 2 FRAGS
E	42	0	0	39	999	3	1	2	1	1	1	4	1	7	4.6	3.3	1.0	19.3	
E	42	0	0	40	999	3	1	2	1	1	1	4	6	7	0.0	0.0	0.0	39.3	4 FRAGS WEIGHED TOGETHER
E	42	0	0	41	999	2	1	2	1	1	1	4	0	7	5.8	2.1	2.8	26.4	1 OF 2, 2ND FRG NOT MEASURED
E	93	0	0	4	999	2	1	2	4	1	1	4	0	7	12.1	5.0	3.2	282.8	
E	58	8502	14	13	999	2	1	2	3	1	1	4	0	2	22.9	19.8	3.1	980.6	1 FRG FITS WITH T59-11E (7 FRGS)
W	29	0	0	97	999	2	1	2	6	1	1	4	0	2	22.5	11.5	1.8	801.7	2 FRGS FIT
E	104	8506	0	13	999	3	3	2	3	2	13	4	6	7	6.6	4.1	4.7	266.7	LOOKS FIRE-CR, GS2 HAS POSS OCHRE?
E	159	8506	0	41	999	2	1	2	1	1	1	1	0	2	9.9	7.2	3.1	327.5	
E	142	8506	0	2	999	3	1	2	1	1	1	4	6	7	5.1	2.9	2.2	41.3	
E	190	8506	0	22	999	3	1	2	1	1	1	4	0	7	3.4	2.1	1.0	7.2	NO PROVENIENCE, BACKFILL
E	155	8506	0	24	999	3	1	2	1	2	1	1	5	7	2.0	1.9	2.0	13.1	
W	14	0	0	1	999	3	1	2	1	1	1	4	0	7	3.9	3.8	2.0	24.3	
W	41	0	0	9	999	3	1	2	1	1	1	4	1	7	3.7	3.0	1.4	33.4	FLAT
W	84	0	0	31	999	3	1	2	1	1	1	4	0	7	5.5	5.3	3.5	77.3	
W	94	0	0	38	999	3	1	2	1	1	1	4	0	7	6.2	5.1	1.9	58.5	
W	37	0	0	11	999	2	1	2	23	1	13	4	0	2	27.1	19.2	4.9	3700.0	
E	170	16858	0	10	999	3	1	2	3	1	1	4	0	7	2.6	1.7	0.7	4.9	2 FRGS FIT
E	172	16858	0	19	999	2	1	2	1	1	1	4	0	7	5.0	3.8	1.4	30.5	
E	173	16858	0	37	999	2	1	2	3	1	1	4	0	7	9.8	7.2	2.8	412.5	FRG MEAS, ALL FRGS WEIGHED
E	136	16858	0	41	999	2	1	2	3	1	1	1	0	7	7.0	6.2	3.7	170.5	
E	146	16858	0	40	999	3	1	2	3	1	1	4	0	7	10.2	9.0	7.2	777.8	ASH STAINED
E	168	16858	0	44	999	2	1	2	2	1	1	4	0	7	22.2	17.3	4.1	1800.0	
E	146	16858	35	62	999	2	1	2	1	1	1	4	0	7	13.2	10.5	2.1	460.3	ASH STAINED
E	146	16858	0	72	999	2	1	2	1	1	1	4	0	7	12.7	10.5	2.4	433.1	CALICHE, NEAR F.35
E	157	16858	0	8	999	2	1	2	1	1	12	4	0	7	10.3	5.0	2.3	134.5	

APPENDIX E

ANALYSIS CODE LIST FOR CERAMICS FROM CANYONLANDS

1. *Provenience*

Includes side of road, site number, unit number, and field specimen (FS).

Typological Categories

Typological assignments were made on the basis of a series of hierarchial decisions. A sherd was placed into a spatially distinctive cultural category (affiliation). It was then assigned to a particular ware group. Finally, it was assigned to a specific type on the basis of surface manipulation and design style. These combinations of codings result in particular ceramic typological categories.

2. *Affiliation*

This variable indicates the postulated area or culture of origin of a particular ceramic item. These include regional and areal ceramic traditions previously defined for the prehistoric Southwest. These assignments are based on a variety of criteria, including temper and paint type, as well as stylistic and technological treatment indicative of ceramics produced within a given area by particular groups. Affiliation codes emplyed include:

IN Indeterminate (Area of origin or cultural association unknown).

MV Mesa Verde Anasazi

KA Kayenta Anasazi

PT Paiute

3. *Ware*

This variable refers to ware categories assigned on the basis of basic surface characteristics. All sherds examined were assigned to a white, red, utility, or indeterminate ware category.

U Utility (Gray)
This category encompasses all ceramics which are unpainted and unpolished and fired in a neutral atmosphere.

W White
This category includes all ceramics which are painted or polished and fired in a neutral atmosphere.

R Red
This category includes ceramics that are painted and polished, and appear to have been intentionally fired in an oxidizing atmosphere. No red ware types were recognized during the present study.

I Indeterminate

This category was employed in cases where one or more surfaces of a sherd was missing, and the ware group could not be determined.

4. *Type*

Sherds assigned to a specific affiliation and ware category were assigned to a particular ceramic type. Ceramic types employed in present study include:

Indeterminate Affiliation

Utility (Gray) Ware Types

- PB Plain Body
- CB Corrugated Body

White Ware Types

- LU Late Unpainted White
- LC Late Carbon Painted White

Indeterminate Ware

- IU Indeterminate Unknown

Mesa Verde Anasazi Affiliation

Utility (Gray) Ware Types

- PB Plain Body
- CB Corrugated Body
- MC Mancos Corrugated (Rim exhibits zero to moderate eversion)
- DC Dolores Corrugated (Rim exhibits moderate eversion)
- VC Mesa Verde Corrugated (Rim exhibits extreme eversion)
- IC Indeterminate Corrugated Rim (Rim eversion determined)

White Ware Types

- LU Late Unpainted White
- LC Late Carbon Painted White
- ME McElmo B/W
- MV Mesa Verde B/W
- PT Pueblo III B/W (Either McElmo or Mesa Verde B/W)

Indeterminate Ware

- IU Indeterminate Unknown

Kayenta Anasazi Affiliation

Utility (Gray) Ware Types

- PB Plain Body
- CB Corrugated Body
- SE Corrugated Rim with Moderate Eversion
- IE Corrugated Rim with Moderate Eversion
- HE Corrugated Rim with Extreme Eversion
- UE Corrugated Rim- eversion not determined

White Ware Types

LU	Late Unpainted White
LC	Late Carbon Painted White
PT	Pueblo III White

Indeterminate White

IU	Indeterminate Unknown

Paiute Affiliation

PI	Incised Surface
PP	Plain Surface

5. *Style*

Not recorded.

6. *Temper*

Material utilized as tempering agents was identified utilizing a binocular microscope. Temper categories utilized during the present study include:

CI	Crushed Igneous
SH	Sherd
SA	Sand
SS	Sand and Sherd
CS	Crushed Igneous and Sand
ST	Sandstone

7. *Paint*

Paint type was assigned on the basis of surface characteristics. Categories recognized include:

N	Paint not present
C	Carbon (Organic)
M	Mineral

8. *Vessel Form*

Represents the probable vessel form or shape. Vessel form categories include:

B	Bowl
J	Jar
H	Jar Handle
I	Indeterminate
W	Olla Rim
M	Miniature
D	Dipper
C	Spiral Coil
S	Seed Jar Rim
P	Pitcher

9. *Modification*

Includes post firing modifications. One modification category [i.e. R Drilled Repair Hole] was recorded in this analysis but is not reflected in data bank.

10. *Rim or Body Sherd*

11. *Total Count*

APPENDIX E

CERAMICS - ISLAND-IN-THE-SKY

E	16858	130	3	999	MV	I	IU	SH	N	I	0	1
E	16858	130	4	999	MV	I	IU	SH	N	I	0	2
E	16858	130	5	999	MV	W	LC	SH	C	B	0	1
E	16858	130	6	999	MV	I	IU	SH	N	I	0	1
E	16858	130	7	999	MV	W	LU	SH	N	B	0	1
E	16858	130	8	999	MV	W	LC	SH	C	B	0	1
E	16858	130	9	999	MV	W	LU	SH	N	B	0	1
E	16858	130	11	999	MV	W	LU	SH	N	B	0	1
E	16858	130	12	999	MV	I	IU	SH	N	I	0	2
E	16858	130	13	999	MV	W	LU	SH	N	B	0	1
E	16858	130	14	999	MV	I	IU	SH	N	B	0	1
E	16858	135	1	999	MV	I	IU	SH	N	I	0	2
E	16858	135	1	999	MV	W	LU	SH	N	B	0	2
E	16858	135	2	999	MV	W	PT	SH	C	B	0	2
E	16858	135	3	999	MV	I	IU	SH	N	I	0	1
E	16858	135	4	999	MV	I	IU	SH	N	I	0	1
E	16858	135	6	999	MV	I	IU	SH	N	I	0	1
E	16858	135	7	999	MV	W	LC	SH	N	J	0	1
E	16858	135	10	999	MV	I	IU	SH	N	I	0	2
E	16858	135	11	999	MV	I	IU	SH	N	I	0	1
E	16858	135	13	999	MV	W	PT	SH	C	J	1	1
E	16858	135	13	999	MV	I	IU	SH	N	I	0	1
E	16858	135	14	999	MV	I	IU	SH	N	I	0	1
E	16858	135	16	999	MV	W	LU	SH	N	J	0	1
E	16858	135	17	999	MV	W	LC	SH	C	J	0	1
E	16858	135	19	999	MV	W	LU	SH	N	J	0	1
E	16858	135	18	999	MV	W	LU	SH	N	B	0	2
E	16858	135	18	999	MV	I	IU	SH	N	I	0	1
E	16858	135	18	999	MV	I	IU	SH	N	I	0	1
E	16858	135	9	999	MV	W	LC	SH	C	J	0	1
E	16858	135	12	999	MV	W	LU	SH	N	B	0	1
E	16858	135	12	999	MV	W	LU	SH	N	J	0	1
E	16858	135	21	999	MV	W	MV	SH	C	B	1	1
												REFIRED(1)
E	16858	135	22	999	MV	I	IU	SH	N	I	0	1
E	16858	135	25	999	MV	I	IU	SH	N	I	0	1
E	16858	135	26	999	MV	W	LC	SH	C	J	0	1
E	16858	135	28	999	MV	W	LC	SH	C	J	0	1
E	16858	135	29	999	MV	W	LU	SH	N	B	0	1
E	16858	135	31	999	MV	W	LU	SH	N	J	0	1
E	16858	135	32	999	MV	I	IU	SH	N	I	0	2
E	16858	135	33	999	MV	W	LC	SH	C	J	0	1
E	16858	136	2	999	MV	W	LU	SH	N	B	0	1
E	16858	136	2	999	MV	W	LU	SH	N	B	0	1
E	16858	136	2	999	MV	I	IU	SH	N	I	0	1
E	16858	136	6	999	MV	I	IU	SH	N	I	0	5
E	16858	135	11	999	MV	I	IU	SH	N	I	0	1
E	16858	136	3	999	MV	I	IU	SH	N	I	0	2
E	16858	136	1	999	MV	W	LC	SH	C	B	0	1

APPENDIX F

KEY TO TAXON CODES

1=*Lepus* sp. (jack rabbit)

2=*Sylvilagus* sp. (cottontail)

3= *Ovis canadensis* (bighorn sheep)

4=*Antilocapra americana* (pronghorn antelope)

5=*Odocoileus hemionus* (mule deer)

6=*Spermophilus* sp. (ground squirrel)

7=*Dipodomys* sp. (kangaroo rat)

8=*Neotoma* sp. (wood rat)

9=*Cynomys* sp. (prairie dog)

10=*Thomomys* sp. (northern pocket gopher)

11=*Geomyidae* (pocket gophers)

12=Bos/*Bison* (cow/bison)

13= *Bison bison* (bison)

14=*Antilocapra*/*Ovis*/*Odocoileus* (antelope/sheep/deer)

15=*Ovis* sp. (sheep)

16=*Bos* sp. (cow)

17=Mammal (medium to large)

18=Cricetidae (rats and mice)

19=Rodentia (rodents)

20=*Ovis aries* (domestic sheep)

Codes

Element: bone name

1=Skull (complete=with maxillae)
2=Hyoid
3=Premaxilla
4=Maxilla
5=Mandible
6=Axis
7=Atlas
8=Scapula
9=Teeth (upper)
10=Teeth(lower)
11=Metapodial
12=Astragalus
13=Sesamoid
14=Phalanx-1st
15=Phalanx-2nd
16=Phalanx-3rd
17=Phalanx-indeterminate
18=Naviculo-cuboid
19=Lateral malleolus
20=Indeterminate tooth
21=Indeterminate vertebra
22=Cervical vertebra
23=Thoracic vertebra
24=Lumbar vertebra
25=Caudal vertebra
26=Rib
27=Humerus
28=Ulna
29=Radius
30=Carpal
31=Metacarpal
32=Femur
33=Tibia
34=Fibula
35=Calcaneus
36=Talus
37=Metatarsal
38=Tarsal
39=Innominate
40=Sacrum

Taxon: species of the bone

1=*Lepus* sp.
2=*Sylvilagus* sp.
3=*Ovis canadensis*
4=*Antilocapra americana*
5=*Odocoileus hemionus*
6=*Spermophilus* sp.
7=*Dipodomys* sp.
8=*Neotoma* sp.
9=*Cynomys* sp.
10=*Thomomys* sp.
11=*Geomyidae*
12=*Bos/Bison*
13=*Bison bison*
14=*Antilocapra/Ovis/Odocoileus*
15=*Ovis* sp.
16=*Bos* sp.
17=Mammal
18=Cricetidae
19=Rodentia
20=*Ovis aries*

Side: what side of the individual the bone is from

1=Right
2=Left
3=NA
0=Indeterminate

Portion: whether a bone is complete or incomplete. If incomplete, what portion of the whole bone is represented.

1=Proximal
2=Distal
3=Lateral
4=Medial
5=Anterior
6=Posterior
7=Diaphysis
8=Complete
9=Superior
10=Dorsal
11=Ventral
0=Indeterminate

ISLAND-IN-THE-SKY

Epiphyses: indicates whether ends and other articular surfaces of bone are fused (grown together) or unfused.

1=Fused
2=Unfused
3=NA or absent
0=Indeterminate

Age: Age at death of individual represented by the bone and based on degree of fusion of epiphyses.

1=Adult
2=Subadult
3=Juvenile
4=Fetal
0=Indeterminate

Adult: an individual with full fusion of epiphyses.
Subadult: an individual where fusion has just occurred or is not quite complete.
Juvenile: an individual with unattached epiphyses.
Fetal: an individual whose epiphyses are unattached and the morphology of the bone indicates it is undeveloped.

Burning: whether the bone is burned or unburned.

1=Burned
0=Unburned

Cut marks: whether butchering marks are present or absent on the bone.

1=Yes
0=No

Breakage: how or when the bone, if a fragment, is broken.

1=Green bone
2=Spiral
3=Recent/post-burial
4=Indeterminate
0=None

Gnawing: whether gnawing is present or absent on the bone and by what type of individual (either a rodent or carnivore).

1=Rodent
2=Carnivore
0=None

The following are codes for provenience information.
Site: if the bone came from an area designated as a site or complex of units, it is entered here.

E orW: indicates if location was on the east or west side of the existing road.

Unit: indicates the number of the unit the bone was excavated from.

FS: represents the field specimen number given to the bone (catalog number).

Feature: if the bone came from a feature within the unit, the number of the feature is entered here.

Depth: this is the level at which the bone was excavated.

0=surface
5=0-5 cmbs (centimeters below surface)
10=5-10 cmbs
15=10-15 cmbs
20=15-20 cmbs
25=20-25 cmbs
30=25-30 cmbs
35=30-35 cmbs
40=35-40 cmbs
45=40-45 cmbs
50=45-50 cmbs
55=50-55 cmbs
60=55-60 cmbs

(Below datum depths are entered as is)

Comments: any extra information on the bone that is not contained in the above fields.

APPENDIX F
FAUNA-ISLAND-IN-THE-SKY

SIDE OF ROAD	SITE NO.	UNIT	FS #	DEPTH	FEA-TURE	ELEMENT	TAXON	SIDE	POR-TION	EPIPHYSES	AGE	BURN-ING	CUT MARKS	BREAK-AGE	GNAW-ING	COMMENTS
E	0	32	1	25	0	28	10	1	8	1	2	0	0	0	0	
E	0	261	3	10	0	26	17	0	11	2	3	1	0	4	0	ID tentative-assoc.w/fea 43? (hist. hearth)
E	0	7	30	80	0	5	11	2	5	3	0	0	0	3	0	from incisor to ascending rasus-teeth=I only
E	0	8	3	25	0	39	7	1	35	3	0	0	0	3	0	mostly ilius and acetabulus-Dipodoays ordii?
E	0	288	1	5	0	24	14	3	0	3	0	0	0	1	2	spinous process fragment
E	0	261	3	10	0	26	17	9	11	2	3	1	0	4	0	ID tentative-assoc. w/fea 43? (hist. hearth)
E	0	261	3	10	0	26	17	0	11	2	3	1	0	4	0	ID tentative-assoc. w/fea 43? (hist. hearth)
E	0	32	1	25	0	32	10	1	7	2	2	0	0	3	0	
E	0	7	30	80	0	5	11	2	5	3	0	0	0	3	0	missing ascending rasus-teeth=I only
E	0	32	1	25	0	5	10	1	5	3	2	0	0	3	0	contains all teeth except M3
E	0	32	1	25	0	5	10	2	8	3	2	0	0	3	0	missing ascending rasus, broken below condyle
E	0	32	1	25	0	28	10	2	8	1	2	0	0	3	0	
E	0	32	1	25	0	33	10	2	27	1	2	0	0	3	0	only missing proximal end
E	SA 415	295	4	5	0	31	5	1	13	1	1	0	0	2	0	
E	SA 415	297	2	5	0	27	2	1	2	2	3	0	0	3	0	
E	SA 421	73	4	25	0	27	4	1	24	1	1	0	0	2	0	taxon tentative, specimen very eroded
W	GR 913	14	120	65	0	29	2	2	8	1	1	0	0	0	2	carnivore gnawing uncertain
W	GR 913	14	120	65	0	29	2	1	2	1	1	0	0	3	0	
W	GR 913	14	120	65	0	35	2	2	8	1	1	0	0	0	0	
W	GR 913	14	120	65	0	35	2	1	8	1	1	0	0	0	0	
W	GR 913	16	4	10	0	7	9	3	8	3	1	0	0	0	0	missing wings
W	GR 913	14	120	65	0	12	2	0	8	1	1	0	0	0	0	
W	GR 913	14	120	65	0	28	2	2	8	1	1	0	0	0	2	carnivore gnawing uncertain
W	GR 913	14	120	65	0	28	2	1	8	1	1	0	0	0	0	
W	GR 913	14	120	65	0	27	2	2	8	1	2	0	0	0	0	proximal epiphysis is just fused
W	GR 913	14	120	65	0	27	2	1	8	1	2	0	0	0	0	proximal epiphysis is just fused
W	GR 913	14	120	65	0	32	2	1	1	1	1	0	0	1	0	

APPENDIX G
HISTORIC ARTIFACTS - ISLAND-IN-THE-SKY

0	00	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	NA None	LEAD BULLET-WITHIN 2M (TO N) of HWY 214
D	1W	0	8	1	0	0	0	0	9	0	0	0	0	0	0	0	0	CA1946 None	1946D PENNY
D	1W	0	8	2	0	0	0	0	0	0	0	0	1	1	0	0	0	NA 31	PORCELAIN CUP HANDLE, INEXPENSIVE
D	1W	0	8	3	0	0	0	0	0	0	1	1	0	0	0	0	0	NA 24	GLASS BOTTLE BASE, MADE BY HAZEL-ATLAS
D	1W	0	8	4	0	0	0	0	0	0	3	2	0	0	0	0	0	CA1950 NONE	TRANSLUCENT CUP/BOWL HANDLE, RIBBED BODY
D	1W	0	8	4	0	0	0	0	0	0	4	1	0	0	0	0	0	NA NONE	GLASS SHERDS
D	1W	0	8	5	0	0	0	1	0	0	0	0	0	0	0	0	0	NA NONE	.22 LONG RIFLE RIMFIRE CARTRIDGE, "C"
D	1W	0	8	5	0	0	0	0	0	0	1	2	0	0	0	0	0	NA NONE	FLUTED GLASS FRAG. W/WHITE PAINT, RED LNS
D	1W	0	8	6	0	0	0	0	0	0	1	3	0	0	0	0	0	NA NONE	AMBER GLASS FRAGMENT, POSS. BEER BOTTLE
D	1W	0	8	7	0	0	0	0	0	0	1	3	0	0	0	0	0	NA NONE	AMBER GLASS SHERD, POSS. FR. BEER BTL. NECK
D	1W	0	8	7	0	0	0	0	0	0	1	1	0	0	0	0	0	NA NONE	TRANSPARENT BOTTLE GLASS SHERD
D	1W	0	8	8	0	0	0	0	0	0	1	1	0	0	0	0	0	NA NONE	HEAVY GLASS BOTTLE SHERD, POSS. MILK BOTTLE
D	1W	0	8	9	0	0	0	0	0	0	1	1	0	0	0	0	0	NA NONE	RIBBED GLASS SHERD, COLORLESS
D	1W	0	8	10	0	0	0	0	0	0	1	1	0	0	0	0	0	NA NONE	GLASS BOTTLE SHERD

REPORT CERTIFICATION

I certify that "Aboriginal Adaptations On The Colorado Plateau: A View From The Island-In-The-Sky, Canyonlands National Park, Utah" by Alan J. Osborn Occasional Studies in Anthropology No. 33

has been reviewed against the criteria contained in 43CFR Part 7 (a)(1) and upon recommendation of the Regional Archeologist has been classified as

Available.

William W. Schenk
Regional Director

May 17, 1995
Date

Classification Key Words:

"Available"-Making the report available to the public meets the criteria of 43CFR 7.18 (a) (1).

"Available (deletions)"-Making the report available with selected information on site locations and/or site characteristics deleted meets the criteria of 43CFR 7.18 (a)(1). A list of pages, maps, paragraphs, etc. that must be deleted for each report in this category is attached.

"Not Available"-Making the report available does not meet the criteria of 43CFR (a)(1).