CHAPTER 5
GIS MODELING OF INTERMEDIATE SCALE LITHIC LANDSCAPES IN THE COLORADO ROCKIES: THE CASE OF BALLINGER DRAW

BY ROBERT H. BRUNSWIG AND DAVID DIGGS

ABSTRACT
The upper section of Ballinger Draw, a small spring-fed stream valley in Colorado’s North Park valley, was intensively pedestrian-surveyed as part of the University of Northern Colorado’s North Park Cultural Landscape Project from 2007 through 2010. Artifact scatters associated with nine sites were identified and documented within the 320 acre research area. One previously recorded site, 5JA421, was partially excavated, revealing three centuries of stratified Late Prehistoric Ute game and plant processing camp occupations, AMS radiocarbon-dated between AD 1080 and 1400. An isolated roasting pit feature at the same site was dated to AD 110 (Early Ceramic) and hearths from two other sites, 5JA1805 and 5JA1808, were dated to 3950 BC and AD 1080 respectively. Several thousand lithic artifacts, including 112 projectile points, were mapped with ArcGIS™ 10.0 software using GPS survey-grade (sub-meter) spatial data. Surface collected projectile point types belonged to Early Paleoindian (Goshen) through Early Historic cultural periods with every regionally known period being represented. This chapter focuses on GIS mapping and statistical spatial analysis (nearest neighbor, cluster) of collective and individual classes of lithic artifacts designed to discriminate prehistoric camp and activity areas throughout the research area. However, except for identifying spatial associations of diagnostic projectile points with some camp and activity area clusters, it is less possible to identify specific chronological-cultural occupation localities within the long-term accumulated archaeological palimpsests draped over the Ballinger Draw land-forms. This chapter also broadly addresses a long-standing archaeological question of what constitutes a “site” versus the a less spatially discrete cultural “landscape”.

BACKGROUND
The University of Northern Colorado’s Anthropology Department began sustained archaeological research in Colorado’s Southern Rocky Mountains in 1998 with a five-year Systemwide Archeological Inventory Program (SAIP) in Rocky Mountain National Park (RMNP). The SAIP project was completed in 2002 after surveying and recording more than 400 prehistoric sites on 30,000 acres, many in remote alpine areas (Brunswig 2005; Doerner and Brunswig 2008). Although smaller research question-driven projects (e.g., spiritual landscape, paleoclimate, and mountain pass archaeo-environmental reconstruction studies) continue in the park, we expanded our research to the adjacent interior mountain basin valley of North Park northwest of Rocky Mountain National Park in 2003. Our long-term approach to conducting archaeological research in the Colorado Rockies emphasizes empirical, field-focused cultural landscape modeling (cf. Chapman 2006; Head 2001; Rossignol and Wandsnider 1992; Ucko and Layton 1999) utilizing Geographic Information System software as a key analytical tool.

Our data for mountain-landscape modeling derive largely from systematic interdisciplinary field studies of selected research polygons, termed research areas, sampled from diverse mountain environmental zones with associated ecological, geological, and hydrological systems ranging from high alpine tundra to mountain valley sage grassland. UNC research areas vary from a hundred to over a thousand acres depending on their ecological and geologic traits and resources. The objective of this chapter is to describe archaeological and GIS landscape analysis of one of our smaller research areas, Ballinger Draw, in northeastern North Park (Figure 5.1).
Ballinger Draw is a third order, ephemeral tributary stream of the Canadian River. The Canadian River headwaters in mountains north and east of North Park, then crosses the park’s northern margins to join the north-flowing North Platte River which exits the valley in its northwestern corner. The Ballinger Draw Research Area consists of 320 acres situated within a 200 m long stretch of the draw’s upper headwaters section, a small east to west trending side valley, and confining hills and east-west narrow ridges. Previous to UNC’s fieldwork, only a single site, 5JA421, had been recorded, but its documented artifact inventory and the presence of bison bone eroding on the surface suggested long-term prehistoric hunting and processing occupations.

Even more significant for our investigations was the research area’s environmental and topographic context; a confining and protective topography, deep alluvial and colluvial sediments where the side valley meets the stream, the presence of local springs, and an unusually rich concentration of Big Sagebrush Steppe plant species, including numerous economically important plants such as

Figure 5.1. Location map of the Ballinger Draw Research Area (labeled Study Area) with an inset map showing its placement within Colorado.
as rice grass, wild onion, golden current, and serviceberry (cf., Bach 2010).

UNC field crew and field school students conducted four seasons of surface-survey and excavations at Ballinger Draw between 2007 and 2010 (Brunswig and Sellet 2007, 2008a, 2008b, 2010, 2011a, 2011b). We identified artifact scatters associated with nine sites and excavated 40 square meters of the earlier recorded 5JA421 site. Excavation of the latter site uncovered a stratified series of shallow (~40 cm deep) continuously stratified game and plant processing camp occupations AMS radiocarbon-dated between AD 1080 and 1400 and affiliated, based on associated pottery and projectile points, with prehistoric Utes. Limited deep testing of selected excavation units found evidence of earlier camp deposits believed to represent Early Ceramic (ca. AD 100-900) Period occupations extending to a maximum depth of 1 meter.

Early Ceramic occupation of the site is attested by a high representation of surface-documented corner-notched projectile points belonging to that period and excavation of a roasting pit feature located outside its main excavation blocks and AMS-dated to AD 110. Other surface-recorded projectile point types provided evidence of earlier Late Paleoindian and Late Archaic site use.

Excavated hearths from two other research area sites, 5JA1805 and 5JA1808, were AMS-dated to 3950 BC (Early Archaic) and AD 1080 (Late Prehistoric) respectively. Several thousand lithic artifacts, including 112 partial to complete projectile points and 129 potsherds from a single Uncompahgre Brownware vessel (Ute), were recovered from surface-surveys and excavations at 5JA421 and limited test excavations of three other Ballinger Draw sites.

This chapter describes research design theory, method, and results of high resolution GIS mapping and statistical analysis of surface artifacts throughout the Ballinger Draw Research Area, with a detailed focus on site 5JA421, the most archaeologically complex and heavily investigated of the Ballinger sites. Addressing all the research area’s sites in detail would entail a longer chapter than appropriate for this volume while a thorough description of UNC’s methodology and results from the 5JA421 site illustrates our overall research strategy and methodologies.

METHODS

GPS Survey and GIS Mapping and Modeling

During the past fifteen years, UNC cultural landscape research programs have systematically utilized geospatial technologies such as Global Positioning System (GPS) survey grade (sub-meter) site-specific, local area (multi-site), and sub-regional landscape documentation and Geographic Information Systems (GIS) mapping and modeling (cf., Brunswig 1997a, 1997b, 1999; 2005a; Brunswig and Diggs 2010; Brunswig, Doerner and Diggs 2012; Brunswig et al. 2009; Diggs and Brunswig 2009, 2012; Doerner and Brunswig 2008).

While standard pedestrian survey methods were followed, e.g., archaeology crew members walking in pre-determined overlapping transects, pin-flagging surface artifacts and features, etc., recording and documentation of archaeological materials have been accomplished within an evolving field documentation system which emphasized both field data record precision and minimal artifact recovery.

Today, UNC field teams systematically record individual sites and associated surface artifact positions with a survey-grade (sub-meter) Differential Global Positioning System (DGPS) unit, in our case the Trimble GeoXT™. At the same time, electronic GPS data are logged and field records and digital photographs of artifact and cultural feature types are recorded along with their materials, physical traits, and dimensions. Archaeological survey spatial data, collected with a survey-grade (sub-meter) GPS unit consistently provided three-dimensional accuracies of ~10-80 cm after computer field data post-processing (cf. Parkinson and Enge 1996).

GIS represents a key tool in our project’s landscape archaeology approach, an approach which has been developed and tested with earlier UNC research programs (cf., Brunswig 2005b; Brunswig et al. 2009;
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Brunswig, Diggs and Montgomery 2007; Diggs and Brunswig 2009, 2011; Diggs and Brunswig 2012).

Lithic Tool Classifications and Analysis for Ballinger Draw

Both formal and informal tools are classified during field and laboratory analysis and documentation within a system of functional artifact classes and types established from past UNC field and laboratory project experience and lithic specialist studies and publications (cf. Andrefsky 1994a: 22-23; 2005a: 31-33 for discussions on formal and informal lithic tool classes). Artifact classification system and working definitions of formal and informal tool classes used for this study are described in more detail elsewhere but are briefly summarized below (cf. Brunswig 2005b:147-150; Brunswig and Sellet 2010: 26-35).

We define formal flaked tools as demonstrating substantial shaping and modification, with >49% of a tool’s working edges showing continuous retouch and/or associated use-wear patterning. Formal flaked lithic tool types include projectile points, knives (hafted and unhafted), scrapers, awls, burins, drills, gravers, spokeshaves, and choppers. Wherever possible, attempts are made to identify multiple functions, such as projectile points alternatively used as knives or scrapers. We also employ working edge angle and micro-wear pattern analyses to assist us in identifying successive use tool histories, e.g., tools which have been “rejuvenated” and transit from one function to serving another, such as broken projectile points having been reworked to serve as hafted or unhafted knives or scrapers.

We define formal ground stone tools as consisting of heavily modified and shaped working surfaces, >49% of total surface area, and including such functional types as grinding-stones (metates), hand-stones (manos), mortars and pestles, generalized abraders (for hides, bone, wood...), grooved shaft-abraders, and hammer-stones. Our informal tool class includes flaked and ground stone tools and defined within two sub-groups: 1) flaked tools with evidence of limited retouched edge modification (<50% working edges), and 2) ground stone tools with working surface wear (edge smoothing, blunting, step-facturing, or grinding...)but also with more limited (<50% of total surface area) shaping or work surface modification. Informal flaked and ground stone tools also include expedient tools with limited edge and work surface wear patterning but little or no evidence of retouch (flaked tools) or abrasion shaping/and or pecking (ground stone and impact tools).

Diagnostic projectile points recovered from Ballinger Draw lithic scatters included complete, partial, and fragmentary specimens. Their typological classification and cultural period affiliations were assigned after macroscopic and low-power microscopic analysis, comparison with publication illustrations and descriptions (Brunswig 2005b; Chenault 1999; Clark 1999; Gilmore 1999; Kornfeld, Frison, and White 2001; Pitblado 2003, 2007; and Tate 1999), and based on past field and lab experience with Western U.S. projectile points by the senior author. It is significant that nearly every known regional cultural period from Early Paleoindian through early historic times is represented at Ballinger Draw sites.

We have classified lithic debitage (tool production and refurbishment waste flakes) according to well-established but intentionally broad lithic tool-production/tool-refurbishment manufacturing stage, or reduction sequence, flake types, e.g., primary, secondary, tertiary, and shatter flakes (cf. Andrefsky 2005a: 187-190, 2005b: 6-7; Brunswig 2005b: 157-161; Cotterell and Kamminga 1987; Flenniken 1984; Magne and Pokotylo 1981; Shott 1994; and Yerkes and Kardulias 1993: 92-99, Figure 1).

Given the large numbers of debitage flakes documented during surface surveys and extensive excavations of 5JA421, two related but less rigorous approaches were utilized in identifying flakes into reduction stage debitage (flake) types. These consisted of survey-based identification of flake debitage based on in-field assessment of basic morphological and size traits (e.g., primary flakes with cortex, thinning and edge removal secondary flakes with or without cortex, tertiary edge retouch flakes, and generalized shattered flakes) and their tabulation during surface survey. Except for selective material type sampling, most survey-recorded
debitage was left in place. Excavation-recovereddebitage was subjected to more precise laboratory identification and tabulation using table top sorting and low-power lens examination of individual flakes.

For surface surveydebitage identification, we adopted use of a utilitarian cortex typology, employing the above noted four flake types: primary (full cortex), secondary (partial or no cortex), tertiary, and shatter (e.g., Morrow 1984 and Stafford 1980 for examples). Because an important survey system goal was to minimize collection and reduce curation costs represented in full recovery of lithic debitage and flake tools, we sacrificed flake class and type field identification accuracy compared to that achievable in the laboratory for time and economy. On the other hand, care was taken in closely examining each piece of surface lithic debitage in situ and hand-recording descriptive traits used to determine flake typology, material type, material source (if known), color, and unusual distinguishing characteristics, e.g., retouch scarring indicating tool refurbishment activity, burning. We also recognize that surface debitage profiles are likely to differ from those recovered from excavated contexts. Surface debitage is normally subject to selective removal or dispersal of flakes depending on size and weight through natural processes such as water and soil erosion, downslope gravity movement, animal burrowing, and trampling (Ensor and Roerner 1989; Kvamme 1996, 1998; Prentiss et al. 1988).

All 5J4421 excavation-recovered flakedebitage was subjected to more detailed morphologic trait analysis (cf. Andrefsky 2005a: 86-131), but limited time and funding prevented comprehensive study of each flake for individual traits such as platform and scar morphologies.

**Lithic Material Sourcing**

Lithic sourcing studies of 5J4421 artifact assemblages, as well as those of the other Ballinger Draw sites, provide good information on the use of local versus more distant, nonlocal, tool material sources. For the purposes of our sourcing research, we define local sources as those known to exist within a 75 km radius while extralocal (nonlocal) lithic sources were defined as those exceeding a 75 km radius boundary. While we realize our definition of local and nonlocal lithic tool sources is somewhat arbitrary, it provides us with a workable standard for separating more localized (local) versus more distant (non-local) resources. We used this boundary as a proxy for hunter-gatherer mobility patterns we felt appropriate for the region, basing it on an estimate of 3-4 days foot-travel in the region at a rate of 15-20 km/day common in often rugged, frequently vertical southern Rockies mountain interior landscapes (for other discussions of nonlocal and extralocal hunter-gatherer lithic source analysis cf. Andrefsky 1994b, 2005a:224-244; Brunswig 2005b:177-178; Jones et al. 2003; Loosely 2000). Others, such as Surrovell (2003) and Prasciunas (this volume) have chosen shorter distance parameters (a generic 20 km linear distance from a site or a radius of 40 km, a day’s foot travel) for defining local versus nonlocal lithic resources. Our use of the longer-distance (75 km) local lithic source definition is driven by our knowledge of past hunter-gatherer access to extensive and widespread regional stone tool resources throughout North Park, Middle Park, and Rocky Mountain National Park (RMNP)(cf. Bamforth 1994, 2006; Black 2000; Brunswig and Sellet 2010: 36-37, 2011a: 47-52; Kornfeld, Frison and White 2001; Metcalf et al. 1991; White 1999; Wunderlich and Brunswig 2004). We also believe there is sufficient research evidence to suggest that 3-4 day travel trips were likely routine to North Park hunter-gatherers given the existence of high-mobility, upland-lowland hunter-gatherer seasonal transhumance patterns in the region for millennia (Brunswig 2004a, 2007: 283-299, 2013).

Ballinger Draw, being in a large interior sedimentary basin valley, provides an abundant source of good quality flakable stone in the form of chert, orthoquartzite, petrified wood, and basalt. The primary local chert type, known as Kremmling (or Troublesome) chert, is a tan to white translucent to opaque chert or chalcedony that is well-documented from sites and prehistoric quarries in Middle Park, south of North Park (Black 2000; Kornfeld, Frison and White 2001; Metcalf et al. 1991; White 1999; Saul 1964; Wunderlich and Brunswig 2004). It also occurs on nearly every hill-top and ridge-line in North Park as
secondary gravels and cobbles, including Ballinger Draw. Surface surveys and excavations at 5JA421 have recovered small Kremmling chert cores and full cortex primary flakes, illustrating local exploitation of ridge top and hill gravels and cobbles.

Another very common local material is Dakota Orthoquartzite, a fine-grained gray quartzite that outcrops at a major quarry (Windy Ridge) in the northwest corner of Middle Park Valley, immediately south of North Park (Bamforth 1994, 2006). Small cobbles of Dakota Orthoquartzite also occur on North Park ridges and hill-tops, including those of Ballinger Draw, and large extinct stream outwash boulders of the material are known from a quarry site in the northwestern corner of North Park. Collectively, Kremmling chert and Dakota Orthoquartzite dominate lithic tools and flakedebitage at all Ballinger Draw sites, ranging in frequency from 65% to 80%.

Another common material type is a dark to medium brown chert, also found on North Park ridges and hilltops, including those in Ballinger Draw. Seven brown chert projectile points found on both the surface and in 5JA421 excavation units were made of locally available North Park brown cherts. Petrified wood, found in substantial quantities at high ridge-lines in the center of North Park, also provided quality tool-stone for past hunter-gatherers.

At 5JA421 and eight other Ballinger Draw sites, a total of one hundred-twelve projectile points and projectile point fragments were recovered from surface surveys and excavation units. Of that number, forty-three (39.39%) are Late Prehistoric types, nineteen (16.96.1%) were Early Ceramic, twelve (10.71%) were either later Late Archaic or early Early Ceramic, ten (8.92%) were Late Archaic, two (1.79%) were Middle Archaic, eleven (9.82%) were Early Archaic, five (4.45%) were Late Paleoindian, and three were Early Paleoindian (Folsom and Goshen) (2.68%) in origin. Seven projectile point fragments (6.25%), mid-sections and tips, could not be type identified.

Our analysis of Ballinger Draw projectile points shows a very high preference for local lithic source materials. A majority (82.5%) of surface-collected projectile points were made of local materials while only 6.25% of surface points came from nonlocal sources. Remaining points (11.25%) were classified as made of unknown source materials. The five nonlocal material projectile points came from multiple wide-ranging sources, including Hartville chert (South Central Wyoming), Bridger (Tiger) chert (northwest Colorado or Southwest Wyoming), oolitic chert from Southwest Wyoming, and Colorado Front Range Dakota Orthoquartzite.

Thirty-two projectile points recovered from excavated Late Prehistoric camp levels at 5JA421, dated between AD 1080-1400, also made of predominantly local materials (75%), followed by those made of nonlocal (12.5%) and unidentified (12.5%) source stone. Four nonlocal material projectile points from excavated site deposits were identified as made of Wyoming Hartville chert (2), Bridger (Tiger) chert (1) from northwest Colorado/Southwest Wyoming, and crystal quartz (1) from Colorado’s South Park valley.

Obsidian artifacts, only recovered from 5JA421 excavations and surface contexts not at other sites, represent an important resource for lithic sourcing and reconstructing migration and trade patterns since their origin sources can be reasonably determined through spectral chemical element analysis. In addition to 5JA421 projectile points made of nonlocal chert and crystal quartz, we also recovered two obsidian points. Both were submitted for energy dispersive X-Ray Fluorescence (XRF) source analysis, with one, a Late Prehistoric point, being made of a recently identified obsidian source in La Poudre Pass, only 30 miles to the southeast, and a similar Late Prehistoric point sourced to Obsidian Cliff, Yellowstone, Wyoming, 430 miles to the northwest.

From 2007 to 2010, five obsidian tools, including the above noted projectile points, and sixty-six flakes were recovered from either the surface of 5JA421 or its excavation units. Of that number, twenty-two were subjected to XRF source analysis (cf., Hughes 2005, 2006, 2007, 2008a, 2008b, 2009, 2010a, 2010b, 2010c, 2012). Nearly every known major source of obsidian in the southern and central Rocky Mountains was identified; Yellowstone National Park (northwest Wyoming), Malad (southeast Idaho), Cerro Del Medio (northern New
Mexico), and Wild Horse Canyon (east central Utah). The majority, however, came from the nearby La Poudre Pass obsidian source on the northwestern corner of Rocky Mountain National Park. However, given that nearly all obsidian came from Late Prehistoric level occupations, dated AD 900-1400, it demonstrates an extraordinary transfer of that lithic material class through direct and/or indirect trade and/or migration in Late Prehistoric times.

5JA421 debitage material source data from surface survey and excavation units are particularly revealing (Table 5.1). More than 5,000 flakes were recorded from the site, including 1,220 surface flakes and 4,034 flakes from excavation levels 1-7. Although a few excavation units penetrated below level 7 (~35 cm below surface), aggregate debitage data from the seven upper levels are used here for comparison with surface debitage data. This allows direct comparison of a relatively and cultural period, the site’s Late Prehistoric AMS-dated stratified occupations, with the site’s longer-term surface-based, multicomponent palimpsest. Levels below 35 cm were judged to represent an earlier Early Ceramic occupation with only limited area excavation evidence.

Lithic material source data from both surface-recorded and excavated lithic waste (debitage) assemblages at 5JA421 allowed us to further assess the relative importance of local versus nonlocal materials for tool manufacturing and refurbishment. Those data, summarized in Table 5.2, demonstrate significant differences in surface versus excavated debitage lithic source data.

Table 5.1. 5JA421 surface and excavation level debitage totals and flake type percentages.

<table>
<thead>
<tr>
<th>Site Context</th>
<th>n</th>
<th>Primary %</th>
<th>Secondary %</th>
<th>Tertiary %</th>
<th>Shatter %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>1220</td>
<td>5.16</td>
<td>53.2</td>
<td>35.57</td>
<td>6.07</td>
</tr>
<tr>
<td>Late Prehistoric Excavation Levels (1-6)</td>
<td>4034</td>
<td>0.05</td>
<td>1.39</td>
<td>91.08</td>
<td>7.49</td>
</tr>
</tbody>
</table>

Table 5.2. Comparison of 5JA421 surface and excavation unit-derived debitage by material source.

<table>
<thead>
<tr>
<th>Site Context</th>
<th>n</th>
<th>Local (within 75 km)</th>
<th>Non-local (beyond 75 km)</th>
<th>Unknown Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>1220</td>
<td>64.6</td>
<td>00.00</td>
<td>35.36</td>
</tr>
<tr>
<td>Late Prehistoric Excavation Levels (1-7)</td>
<td>4034</td>
<td>85.58</td>
<td>14.26</td>
<td>0.16</td>
</tr>
</tbody>
</table>
Two factors are believed to account for the differences. First, identification of survey flake sources was done in the field at the time of recording and if there was any question whether flakes were of local or non-local origin, they were simply designated unknown, explaining the high percentage of unknown source material. Excavated debitage, on the other hand, benefited from laboratory analysis and direct macroscopic, microscopic, and UV fluorescence analysis comparison with lithic samples from seven mountain and plains states in UNC’s lithic source collection. This allowed greater accuracy in determining excavated debitage sources. Even factoring in potential errors from the lack of lab-based source identification of uncollected informal tools and debitage during surface survey, it is apparent there was significant use of local source materials ranging from 65% (surface survey) to 86% (from Late Prehistoric excavation units). It is also certain that variability in flake source materials exists in different site surface clusters given they are part of a complex palimpsest of different period occupations, each of which may have had left differing local to non-local lithic material patterning. This latter possibility will be explored in subsequent GIS analysis of surface data sets.

METHODS AND RESULTS OF GIS STATISTICAL ANALYSIS OF 5JA421 SURFACE LITHIC ARTIFACTS

Our first step in GIS mapping and analysis of Ballinger Draw artifacts was assembly of a database file of all surface artifacts, their types, and spatial locations. Figure 5.2 shows a GIS map overview of the Ballinger Draw.

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Figure 5.2. GIS map of GPS-recorded surface artifacts and sites (artifact clusters) overlaid on a 1 m resolution geo-referenced NAIP aerial photo. Note the Ballinger Draw stream channel in the upper left and the side-valley ridge lines and interior valley from upper left to lower right.
Research Area with projections of artifact clusters that constitute individual sites. Note that two of the sites, 5JA421 and 5JA1810, tend to converge along their eastern and western margins, respectively. Technically, that convergence normally means they would be classified as a single site. However, we ultimately decided to designate them as separate sites due to our perception they appeared to represent two relatively distinct cultural phenomena, e.g., a dense stratified concentration of animal and plant processing camps with probable outlier activity, later stage processing areas (5JA421) and a ridge-top series of short-term living camps repeatedly in use over more than ten millennia (5JA1810).

Remaining sites in the area appear, on the basis of archaeological evidence, to represent a mix of short-term hunting and gathering camps (5JA1805, 5JA1807, 5JA1809, and 5JA1812) and physically discrete special purpose activity areas (5JA1806 and 5JA1811). We made the distinction between camps and activity areas as camps having multi-use tool kits and hearths and/or roasting pits while activity areas were inferred by their limited tool types and general lack of hearth (fire-cracked rock [FCR] and/or small rock rings) or roasting pit (FCR concentration) features.

5JA1806 and 5JA1808 represent somewhat unusual cases. 5JA1806 is a scatter of heavily weathered artiodactyl bone, possibly elk, eroding out of a ridge-slope drainage swale with associated flake debitage and a single Early Archaic projectile point. Our working hypothesis for 5JA1806 is it represents a single kill and butchering event where a post-butchering event carcass was rapidly buried by slope erosion colluvium and only recently re-exposed by modern erosion. The second case, 5JA1808, was a rock-filled hearth or roasting pit buried by alluvium in an upper Ballinger Draw spring-fed fen. It was discovered during profile cleaning of a deep head-cut eroding into the fen from down-stream. The buried feature’s upper portion was 60 cm below the modern fen surface and in situ charcoal was AMS-radiocarbon dated.
Figure 5.3 (above) shows the distribution of projectile points, formal tools, and informal tools for all Ballinger Draw sites, but omits the “clutter” ofdebitage locations (see Figure 5.2) which, in the denser sites, obscures visualization of lithic tool locations. What is significant about this GIS map is it shows that most of the sites and outlier artifact clusters of the two larger sites (5JA421 and 5JA1810) are more than simply flake concentrations, but most have activity-related lithic tools and culturally chronologically diagnostic projectile points.

GIS analysis within individual sites, particularly those with high artifact densities, provides a number of potential advantages for both analysis and interpretation of spatial distributions of individual tool types or collective mixes of tool types anddebitage. When used in large areas such as the Ballinger Draw Research Area, GIS spatial analysis offers the opportunity to experiment with (and model) a siteless archaeology approach, allowing surface distributions of archaeological materials to potentially reveal landscape patterning of past human behavior (cf. Dunnell and Dancy 1983; Ebert 1992; Kvamme 1998: 127-129). Of course the effectiveness of a siteless survey strategy depends on surface artifact visibility, constrained natural conditions for rapid and deep burial of archaeological remains (alluviation, colluviation, eolian action), and minimal surface disturbance (water and wind erosion, human and animal actions).

Spatial pattern analysis techniques used in this study allowed us to assess the statistical validity of observed spatial clustering and/or dispersion of surface artifacts. It is important to remember that just because a pattern (in this case of various artifacts and their associated classes) appears “clustered” or “dispersed” to the human eye, it doesn’t mean that the apparent clustering/dispersal can stand up to the rigors of geostatistical testing.

In the following section, we use our results of archaeological and GIS analyses of 5JA421 to illustrate how we applied our GIS-enabled research design and methodologies to reconstruct Ballinger Draw’s prehistoric landscape. For instance, in our early investigations at 5JA421, we assembled GPS field data from the originally documented site area (cf., Armstrong and Struthers 1980; Rupp 1992) into a series of archaeological artifact class GIS layers. Subsequently, we expanded our surface surveys and GPS recording of artifacts outward from the site, expanding its artifact-scatter defined boundaries each new project year. We used projections of GIS maps and density patterns to guide our placement of excavation units. Those projections, as we demonstrate below, became increasingly useful as survey data and GIS mapping progressed project year to project year.

In our first year (2007), we excavated three separate test excavation units based in part on artifact surface density. In years 2 (2008), 3 (2009), and 4 (2010), we expanded the original test units into their own multi-unit excavation blocks, eventually excavating a total of 48 1 m² excavation units. GIS mapping of surface materials played an important role in situating and expanding excavation blocks for maximum effect. Figure 5.4 shows side-by-side GIS maps graphics of surface flake debitage and fire-cracked rock (FCR) distribution patterns with an inset map of the final excavation blocks and units.

Debitage and fire-cracked rock (inferred hearth or roasting pit locations) distribution and clustering patterns were used, along with topographic variables (e.g., stream terrace versus hill-slope), to help to inform excavation placement strategy. As shown in Figure 5.4, placement and expansion of the site’s excavation blocks closely mirrored its densest surface artifact cluster patterning. Density patterning also suggests that even more subsurface deposits lie well beyond currently excavated areas.
GIS ANALYSIS METHODOLOGY

ArcGIS™ 10.0 has a number of statistical techniques which allowed us to assess distribution and clustering of surface artifacts within site boundaries, including average nearest neighbor analysis, multi-distance spatial clustering (using Ripley’s K function), and hot spot/cold spot analysis (e.g., Rosenshein 2010a, 2010b).

A particularly powerful tool was hot and cold spot analysis. Hot and cold spot analysis is a data analysis technique used to examine concentration and dispersion in spatial datasets, their sub-classes, visually interesting patterns, and identification of outlier artifact clusters (Gibbs 2012; Gordon 1999; Johnston 2012; Maes 2012). Areas are highlighted within the context of geostatistics, identifying statistically significant areas of clusters and dispersion (cf., Rosensheim 2010a, 2010b; Spiker and Warner 2007: 201-202). Archaeological applications of GIS-based hot spot/cold spot analysis range from macro (regional) and meso (mid-level landscapes, such as Ballinger Draw) scales to site-specific micro-scales (Crema, Bevin and Lake 2010; Johnston 2010; Kvamme 1996, 1998).

In the case of 5JA421, we initially observed what appeared to be clear visual clustering of different artifact categories in GIS plot maps and, with advanced statistical correlation and cluster analyses, found much of that clustering to be statistically confirmed. A more nuanced view within the site’s boundaries showed that, while there were numerous small areas of very intense artifact clustering (hot spots), other areas, while appearing to be clustered, simply were not as statistically significant. This suggests that purely GIS visualized artifact clustering on a landscape may, in at least some cases, be more apparent than real when subjected to statistical testing. This discovery also helped us better focus our field investigations as they advanced year-by-year, e.g., targeting certain site area locations for archaeological testing and excavation where surface evidence of past cultural activity appeared most focused.

The spatial pattern characteristics of individual categories of artifacts (i.e. formal tools,debitage, etc.) were analyzed in a four step process. First, the average nearest neighbor technique was applied to each surface artifact category. Second, the Multi-Distance Spatial
Clustering (Ripley’s K function) was determined for each category. Third, the data was re-compiled for use in Hot/Cold Spot Analysis. Finally, this recompiled data was used to conduct Hot/Cold Spot Analysis. Each step helped us to understand one part of the distribution pattern of each artifact category. In addition, each step informed us for the selection of parameters in each next step.

The distribution of a surface artifact category was first analyzed using the Average Nearest Neighbor tool in ArcGIS. This technique told us whether a dataset of points (artifact category) was clustered, random, or dispersed. Our null hypothesis was that the artifacts were randomly distributed. In most cases we were able to reject the null hypothesis (using z-scores and p-values calculated by the tool) and state that, for example, fire-cracked rock was clustered and its cluster patterns were statistically significant. This approach constitutes a broad measure of clustering, but it doesn’t really tell us anything about ‘where’ within the site clustering occurs. It’s true that in many cases the technique simply verifies what is visually obvious.

At this step in the process, we knew a given artifact category was “clustered” but we wanted to examine the nature of that clustering more in-depth. The Multi-Distance Spatial Cluster Analysis (Ripley’ K Function) tool aided us in assessing statistically significant clustering or dispersion over a range of distances. Presented in graphical form, the technique helped us to assess whether already proven clustering (via Average Nearest Neighbor) was focused in a relatively small distance range or whether the clustering was more spread out. But again, while useful in identifying more specifically the nature of the clustering, the technique also did not tell us precisely ‘where’ the clustering is strongest or weakest within the site.

Our third and next step in analysis of the clustering/dispersion of artifact categories was a data preparation step. In order to analyze the ‘where’ of clustering/dispersion our data needed to be weighted. As is, the data are simply nominal in nature. That is, one artifact at one location. The Hot Spot Analysis (Getis-Ord Gi*) technique requires input data to be in interval or ratio format. We used two tools in ArcGIS to create this weighted data. First, the Integrate tool was used to set a predefined distance, which then “snapped” together nearby events (each artifact). The Collect Events tool then provided a ‘count’ of events (artifacts) at each location. The distance tolerance input for the Integrate tool is a key decision. We selected relatively small distances for most of the artifacts, between .5 and 2 meters. Two important caveats about this process need to be noted. First, selection of the distance tolerance is somewhat arbitrary. However, we felt that our use of relatively small distances did not significantly alter the nature of the data. Second, the Integrate/Collect process significantly decreased the number of points used in subsequent geostatistical analysis. In some cases the reduction in points can make our next step (Hot/Cold Spot Analysis) nonviable because of small sample size.

Our final step was to use ArcGIS’s Hot Spot Analysis (Getis-Ord Gi*) tool to explore artifact distributions within the site. This technique has the potential of showing areas within the sites that are hot spots (statistically significant clustering) and cold spots (statistically significant dispersion). Our results, described below, varied with different artifact categories.

**Formal Tools Analysis Results**

The Average Nearest Neighbor analysis indicated that formal tools are clearly clustered with a mean distance between formal tools of 8.6m (random expectation 18m). Both Z-score and p-value for this analysis affirmed that formal tools had statistically distinctive clustering (Table 5.3). The Multi-Distance Spatial Clustering (Ripley’s K function) results showed most of the clustering within a 40 to 120 meter diameter polygon along the east stream-side bank area of the site with perhaps a weak peak within a 55 meter zone.
Figure 5.5 (above) shows the result of our Hot/Cold spot analysis of formal tools, including projectile points. The map on the left shows an interpolated surface that uses Z-scores from the hot/spot analysis output. A one-tailed test of z-scores indicates that interpolated areas with a Z-score greater than 1.64 are statistically significant hot spots for formal tools. Alternatively, statistically significant cold spots should have a z-score lower than -1.64. There are no statistically significant cold spots of formal tools. The map on the right in Figure 5.5 shows only the formal tool hot spot areas which are statistically significant at the .05 level (z-scores greater than 1.64). This is a very limited area which closely conforms to our GIS map informed placement of 5JA421 excavation units (see earlier Figure 5.4).

Table 5.3. Average Nearest Neighbor Summary of Formal Tool data for site 5JA421. n = 90.

<table>
<thead>
<tr>
<th>Observed Mean Distance</th>
<th>8.639m</th>
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<tbody>
<tr>
<td>Expected Mean Distance</td>
<td>18.062</td>
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<tr>
<td>Nearest Neighbor Ratio</td>
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<td>Z-Score</td>
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<td>p-value</td>
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</table>

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Assorted, Less Frequent Artifact Types Analysis Results
Surface surveys of 5JA421 yielded small numbers of associated bone, informal tools, ceramics, and ground stone, but bone was only recorded if it could reasonably be attributed as archaeological in origin, not from modern or recent historic sources. Archaeological versus non-archaeological bone determinations were field-based using such criteria as observations of bone emerging onto the surface through erosion and consisting of faunal material clearly not of recent origin, such as bison bone, a species eradicated from the region a century and a half earlier. The fully involved hot spot analysis process, described above, was not conducted on these latter artifact subsets due to their small sample sizes. However, most secondary cultural material categories exhibited significant statistical clustering, although it was not possible to accurately assess their spatial intensity.

Debitage Analysis Results
As described earlier, the single largest amount of artifact material documented in 5JA421 surface surveys as well as in excavations was lithic tool manufacturing and refurbishment waste (debitage). As shown in the earlier Figure 5.4, there is apparent clustering ofdebitage throughout the site’s 43 acres, but we also needed to determine if the GIS-visualized distribution pattern was
statistically significant. We conducted Average Nearest neighbor Analysis ondebitage points to assess overall clustering. Our analysis results (see Table 5.4) indicated a mean cluster distance of 2 meters between debitage points, showing statistically significant clustering of debitage. A random distribution would have returned an expected mean distance of 4.9 meters. These results confirmed our visual impression that the overall distribution of debitage was clustered. Multi-Distance Spatial Cluster analysis (Ripleys K Function) showed debitage most strongly clustered around 60 meters, with overall clustering terminating at ~170 meters.

The left-side map in Figure 5.6 shows an interpolated plot of debitage hot spots. Darker shaded areas represent areas of statistically significant intense lithic debitage. The lightest shaded areas represent cold spots which, if even appearing somewhat clustered, have statistically less significant intense debitage concentrations. Both the light and darkest points have significantly low or high Z-scores of less than a .01 chance of being random. The right-side map on in Figure 5.6 focuses only on statistically significant (.05) debitage hot spots (clustering). Hot spot analysis clearly shows intense debitage clustering coinciding with earlier described formal tool hot spots and in the same general locations as the 2007-2010 excavation blocks.

**Fire Cracked Rock Analysis Results**

We also analyzed fire cracked rock (FCR) distributions for statistical significance. In Ballinger Draw, fire-cracked rock is visually recognizable as fire-reddened and heat-fractured rock lying on the surface, normally consisting of cobbles and cobble fragments of quartzite and quartz and inferred as representing former hearth or roasting pit locations. Our FCR data set consisted of a 257 individual FCR rocks, or if they were a closely spaced (within .5 m) FCR cluster they were recorded as a single GPS point.

![Figure 5.7. Cold (lighter shades) and Hot (darkest shades) Spot Analysis of SJA421 FCR.](image)
While GIS-mapped patterns of FCR distributions appeared well-clustered to the naked eye (see Figure 5.4 above), we needed to substantiate that observation through statistical analysis. We found results of average nearest neighbor analysis (Table 5.5) and the Multi-Distance Spatial Clustering (Ripleys K function) analysis showed fire-cracked rock was strongly clustered at a peak of about 70 meters. Hot spot analysis, however, showed that areas of statistically significant clustering were very small and focused at only few locations within the site (Figure 5.7).

Our interpolated map (using kriging) of FCR clustering (Figure 5.7, left map) suggests intense clustering in the east central portion of the site, but this is misleading. The statistically accurate situation (Figure 5.7, right hand map) shows the interpolated surface (again using kriging) of p-values for 5J4A21; with those darkest areas with .05 or lower values (statistically significant) while the bulk of the site has less significant p-values greater than .05. Interpretation of FCR analysis results confirm the probable significance of surface FCR density as an indicator of concentrated subsurface deposits. The majority of FCR hot spots occur within the general areas of formal tool and debitage hot spots and excavation blocks. However, a few FCR hot spots in the site’s south and southwest quadrant suggest the presence of other camp or specialized activity (camp hearths, roasting pits…) areas. These areas should be targeted if excavations are resumed at the site in the future.

CONCLUSIONS

The merging of theory, method, and practice in archaeology is a long and productive tradition. What is revolutionary since the advent of the New Archaeology Paradigm a half century ago is that our tools for acquiring and analyzing ever more accurate and detailed archaeological data in the field and laboratory continue to advance at an ever-accelerating pace. Among the most useful tools for archaeology today are Global Positioning System (GPS) and Geographic Information System (GIS) technologies. Merged with careful, traditional field survey and excavation methodologies, they allow us to accurately document three-dimensional imagery of modern residues of ancient technological remains on the landscape and better conceptualize and test hypothetical scenarios of past human cultural behavior.

In the preceding chapter, we have described a system of archaeological data collection that fuses traditional field methods with 21st century technology, both contributing to reconstructing and modeling prehistoric cultural systems at multiple scales of inquiry, from the individual site to localized geographic areas with shared geologic and natural conditions to geographic sub-regions and regions. Like the prehistoric peoples who once lived on the landscapes we study, we ourselves are changing and evolving in how we extract usable information from the archaeological record and apply new and old theory, method, and practice and emerging and future technologies in the quest for their better understanding and appreciation.

Table 5.5. Average Nearest Neighbor Summary of Fire Cracked Rock data for site JA421. n = 257

<table>
<thead>
<tr>
<th>Observed Mean Distance</th>
<th>4.442m</th>
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<tr>
<td>Expected Mean Distance</td>
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<tr>
<td>Nearest Neighbor Ratio</td>
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<td>Z-Score</td>
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<tr>
<td>p-value</td>
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</table>
REFERENCES CITED


LITHICS IN THE WEST

presented at the Chacmool Archaeological Conference, University of Calgary, Calgary.


LITHICS IN THE WEST


