AN ANALYSIS OF QUARRYING BEHAVIOR AT ALIBATES FLINT QUARRIES NATIONAL MONUMENT, FRITCH, TEXAS

THESIS

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by

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DEDICATION

I dedicate this work to my wife, Jan:
Amantes sunt amentes!
Lucky I to be a madman

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CHAPTER I

INTRODUCTION

What is presently referred to as the "Antelope Creek Phase" represents a unique society extant along the North and South Canadian and Beaver rivers in the Oklahoma and Texas panhandles from A.D. 1200- 1500 (Figure 1-1) (Baker and Baker 2000; Brooks 1994, 2004; Brosowske 2005; Hughes 1991; Krieger 1946; Lintz 1986).

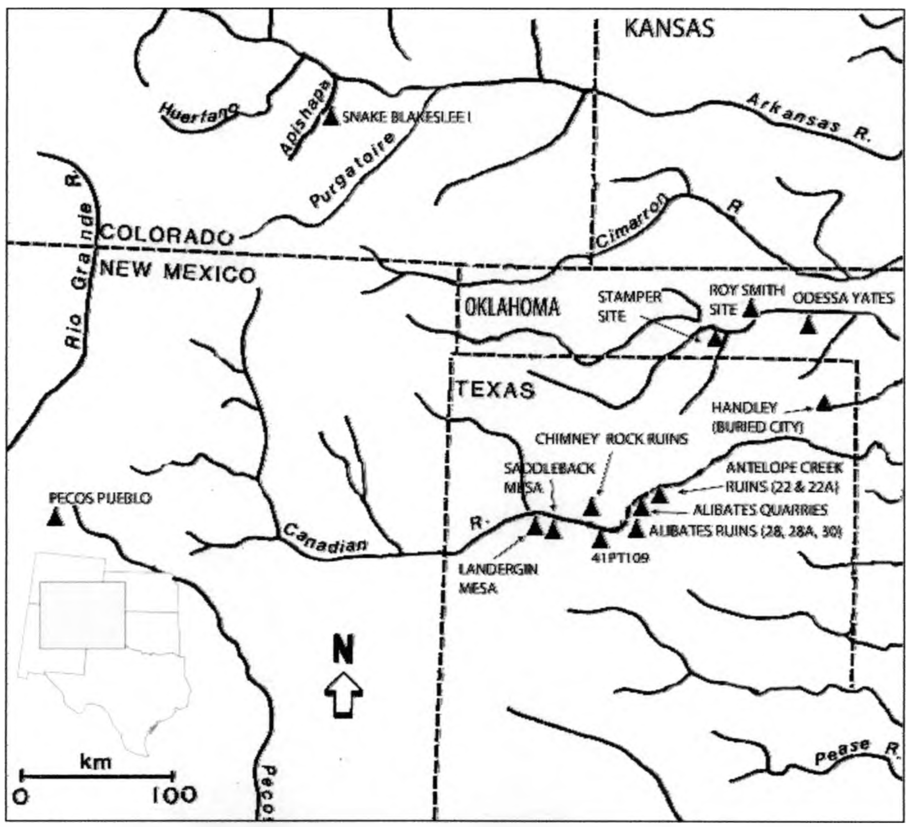


Figure 1-1. Area of thesis research, showing sites mentioned in text. Adapted from Lintz (1986:9).

Antelope Creek sites contain elements of both Plains and Southwestern cultures. While exhibiting an architecture that has some similarities to southwestern Pueblo and Plains styles, Antelope Creek structures have attributes that are unique, such as the use of upright limestone slabs as masonry (Baker and Baker 2000; Brooks 1994, 2004; Hughes 1991; Lintz 1986). There is evidence for agricultural subsistence and even more evidence for hunting and gathering (Brosowske 2005; Ruff 1994). The lithic and ceramic assemblages found at Antelope Creek sites are Plains in nature. Despite these apparent influences, the exact "ancestry" of Antelope Creek is not known, though there have been a number of attempts to delineate it (Baker and Baker 2000; Brooks 1994, 2004; Brosowske 2005; Hughes 1991; Krieger 1946; Lintz 1986). Current thinking about Antelope Creek society is that it was more sophisticated than originally thought, and may have had a complex economy involving extensive exchange networks (Brosowske 2005; Campbell 1969). While many excavations have been completed in the area, until recently, most were done without the use of contemporary field methods and techniques, thus making inferences about their society more difficult to resolve. Chapter II contains an overview of this region's archaeological research trajectory.

Nestled in the midst of the area's Antelope Creek occupational sites is a huge quarry area where Alibates chert, a unique form silicified or agatized dolomite, was mined (Figure 1-1). All that is left of the quarrying activities are shallow depressions that cover over a thousand acres. Outcrops of chert cap the bluff; there are occasional boulders of red and white weathered chert, and millions of chips and chunks of multi-colored chert debitage cover the ground. First mentioned by Lt. J. W. Abert in 1845, it remained for Charles N. Gould in 1917 to name the white dolomite "Alibates" after nearby Alibates Creek (Carroll 1941:64-69; Gould 1917:9). However, in a speech dedicating an official Texas State Historical Marker in honor of Gould, H. E. Hertner claimed that the name of Alibates flint was a corruption of the name of "Allen Bates", a local rancher's son on whose land Alibates Creek is located (Banks 1990:91; Bowers 1975:5). Gould (1907:9-11) described the Alibates chert as comprising an upper bed of dolomite, followed by a red-bed sequence, followed by a lower dolomite bed, and compared it to Day Creek Oklahoma dolomite.

Banks (1990:91) wrote that "Alibates 'flints' are possibly more widely reported in archaeological literature than any other single lithic resource". Banks (1990:91) also noted "that the Alibates materials probably have received greater distribution temporally and culturally on a geographic basis than any other single chert type." Nonetheless, due to physical variability in physical characteristics, there is no agreed upon description of Alibates chert (Banks 1990; Bowers 1975). Bowers (1975) is credited with the only intensive study of Alibates chert. He suggested an origin for most of the chert, attributing chertification of the dolomite to secondary replacement from the silica-rich Ogallala as a by-product of the calcification process (Banks 1990:91; Bowers 1975:6). Prevailing thinking about the Alibates quarries was that they were turned into a "blank-making" industry by the local Indians, and that those blanks were traded throughout the Southwest, eventually reaching "such places as the Pacific Coast and Minnesota", but Bowers posited that "only a positive method of identifying the chert [would] increase or decrease the geographic range of trading" (Bowers 1975:7).

In 1965, after a lengthy campaign, Congress established Alibates Flint Quarries National Monument (Alibates Quarries), Texas' only National Monument. Bousman

(1974:10) noted that the few surveys of the Alibates Quarries completed at the time of his assessment, merely "emphasize(d) how little is known about the quarries." He further noted that more reliable data must be collected about the site in order to properly understand how people used the quarries. Most research in the area continues to be focused on architectural/occupational ruins, with little but passing mention given to the quarry pits. Chapter III is an overview of not only research at Alibates Quarries, in particular, but also important prehistoric quarries research done in Europe.

In 1993, the Alibates Quarries was engulfed in a huge grass fire that burned all 1,079 acres (Katz and Katz (2003:iii). This event, while tragic, allowed for an unprecedented visual inspection of the entire Monument property. The National Park Service contracted Susana Katz and Paul Katz (Katz and Katz 2003) to conduct a comprehensive archaeological survey of the burn area. They produced a document that remains unpublished (Katz and Katz 2003). In addition to surveying archaeological sites (including quarry pit locations), Katz and Katz excavated two isolated quarry pits. The results of this excavation have also not been published. In 2008, Paul Katz allowed this author access to the raw Sokkia Data Station pit location data that was collected in the 1993 survey (Katz and Katz 1993a, 1993b). These data were neither converted into corrected UTMs, nor were they rendered into a map. Chapter V articulates the methods used by the Katz and Katz 1993 survey. In addition, it articulates the methods used to analyze their data set. Chapter IV contains an overview of the theoretical perspectives of spatial analysis as used in interpreting field observations and data, as well as the research design and models that guided the research for this thesis.

Part of this thesis work is the creation of the first geo-referenced map of all the quarry pits Katz and Katz (1993a, 1993b, 2003) located within Alibates Quarries. Presented in Chapter VI, is the map created as the result of this investigation. Also presented in this chapter are the spatial analyses performed on the Katz' pit location data that show patterned clustering of the quarry pits at Alibates Quarries. A discussion of the results of these analyses indicates that it could confirm what researchers have previously inferred from other evidence (Brooks 2004; Brosowske 2005; Hughes 1991; Lintz 1986). Problems encountered with the Katz and Katz (1993a, 1993b) data are also articulated within Chapter VI. Suggestions for future research based on the results of this thesis, are presented in Chapter VII.

CHAPTER II

ANTELOPE CREEK RESEARCH OVERVIEW

That there were prehistoric ruins scattered through the Texas panhandle was known well before they caught the eye of Floyd V. Studer in 1907. Soldiers surveying the area in the mid to late 19th century noted their occurrence in their diaries. In 1845, Lt. J. W. Abert, while scouting the area with the U.S. Cavalry, described both ruins and the flint quarries he observed, and in 1876, Lt. Thomas M. Woodruff, also scouting for the Cavalry, took away flint arrow points (Carroll 1941).

Studer was a young student of 15 attending Canadian Academy, when, in 1907, he persuaded his history professor, T. L. Eyerly, to investigate ruins at the Handley Brothers Ranch, located some 12 miles from Ochlitree, Texas, on the south bank of Wolf Creek (Figure 1.1) (Eyerly 1907:219; Rathjen 1998:35, 2008). Visiting the site, Eyerly was intrigued by the signature way in which stones were placed standing upright around the exposed foundations of what he thought were tombs (Eyerly 1907:222). What he found were scattered human remains and evidence of burning. Eyerly was convinced he had found the remains of a massacre: one of the human bones even had an obvious arrow point embedded in it (Eyerly 1907:222). Considered one of the earliest, if not the first, formal archaeological excavation undertaken in the state of Texas, Eyerly's team measured and described what they found, albeit without the benefit of modern methodologies. Among his conclusions, Eyerly argued that the human remains were associated with the structures and that the architects were "more advanced in civilization than were the majority of Plains Indians" (Eyerly 1907:228). Eyerly, despite this comment, did not believe the builders of this ruin were Aztec or Mesoamerican as was popular in those days, but were indeed Plains Indians (Eyerly 1907:227). He dubbed the Handley site "The Buried City of the Panhandle" (Eyerly 1907:228).

Eyerly's account drew J.W. Fewkes of The Bureau of American Ethnology at the Smithsonian Institution in Washington D.C., who also recovered human remains from the site (Moorehead 1921:2). Fewkes was an expert on Zuni and Hopi religious ceremonies and had published more than 68 volumes on Native American ethnography (Hough 1931). If Fewkes had had any opinion about his finds from the Panhandle area, he never published them. In 1891, C.B. Franklin, a well known amateur archaeologist from Arkansas, visited the site in 1919 (Franklin 1919) and reported 26 buildings at "Buried City" (Franklin 1919:1), all constructed as Eyerly had described. Franklin documented hundreds of structures in the nearby area, some with "battlements" (Franklin 1919:2). Franklin wrote of evidence of cultivation at the site, and claimed to have found "pots with food" (Franklin 1919:2). As to burials, Franklin noted that "for miles around hundreds of graves can be found" with remains in all forms of final repose, "but those in the City seemed to be left where they fell or where the walls crushed them" (Franklin 1919:2).

Warren K. Moorehead, the well-known founder of the Peabody Institute at Phillips Academy in Andover, Massachusetts, also visited the site in 1919 (Anderson 2008; Moorehead 1921). Moorehead excavated several ruins. Among the sites he describes for the first time are "King's ruins", now known as Alibates Ruin Number 28 (41PT11), and the ruins atop Landergin Mesa (41OL2) (Figure 1-1) (Moorehead 1921:3, 4).

Moorehead related the sites found in the Texas Panhandle to those found in parts of Oklahoma Panhandle, but observed that "beginning in central Oklahoma, we note a change from the general culture of the Mississippi valley tribes" (Moorehead 1921:6, 8). Moorehead inferred the cultural boundaries between Mississippian, Plains and Pueblo culture by looking at artifact assemblages. After noting the lack of "true Pueblo-cliff Dweller pottery," Moorehead acknowledged the work of Alfred Kidder, and expressed doubt "that Indians would lose, or discard, their skill as potters" (Moorehead 1921:10). At the time of Moorehead's reconnaissance of the Texas Panhandle, Kidder had not yet published his important summary, *An Introduction to the Study of Southwestern Archaeology,* yet researchers such as Moorehead were well aware of the near-decade long excavations Kidder had been mounting at Pecos Pueblo in New Mexico, and of the radical methodology he was using there (Figure 1-1) (Schwartz 2000:1-25). Kidder had developed a five-step methodology consisting of mapping and reconnaissance; the selection of correlation criteria for ranking sites chronologically; the seriation of recovered artifacts into a logical sequence; carefully documented stratigraphic excavation in order to further evaluate specific problems; followed by more detailed regional survey and dating (Kidder 2000[1924]; Schwartz 2000). Kidder organized his observations into a regional pattern of cultural chronological evolution and Moorehead wanted to draw the same types of broad conclusions from his own observations.

Moorehead saw the Panhandle region's architectural remains as marking "the beginning of architecture in stone in the Southwest" (Moorehead 1921:8). He assumed that the larger clusters of structures were of later construction, and further notes that "Puebloan people did occasionally migrate" as far as western Kansas (Moorehead 1921:10). Moorehead observed there was no evidence to support a Mexican influence on the ruins. He further concluded that the cultural remains pointed toward the inhabitants as having been "a tribe originally living in the buffalo country and of 'Plains Culture' status which changed as it spread westward up the Canadian" River (Moorehead 1921:11).

Investigations continued with those conducted by W. C. Holden in 1929, J. Alden Mason, also in 1929, and E. B. Sayles in 1931 (Holden 1929, 1931; Mason 1929; Sayles 1932). Krieger (1946:23) quoted Holden (in a letter to Moorehead) as positing that "the Panhandle culture had no relationship to the Southwestern Pueblo culture," that it was "a glorified Plains development which existed during early Pueblo time or before." In his summary of 1930 field work, Holden further contended that later "Pueblo Indians" used the architectural ruins in the Canadian River area as temporary camps while hunting buffalo (Holden 1931:52). Mason asserted that the Canadian River valley "served as a trade route between Puebloans and Plains Indians" because he had found "small bits" of pottery similar to those found in Pecos Pueblo (Krieger 1946:19; Mason 1929). However, Mason (1929:326) wrote that the potsherds "represent merely temporary camps of the Pecos people while on expeditions to hunt bison." Holden and Sayles interpreted dendrochronological data along with analysis of recovered pottery (Pueblo trade sherds) to pinpoint the date of Saddleback ruin to A.D. 1350 (Figure 1-1) (Holden 1932:291; Sayles 1932). They also noted variation in architectural styles between the Antelope Creek and Saddleback sites (Holden 1932:291; Sayles 1932).

By the late 1920s, methodology, such as Kidder's stratigraphic analysis, was coming into general use. Archaeologists were beginning to use seriation and stratigraphy to deal with the idea of cultural development, and developing cultural classification systems. What began with Kidder's culture-historical synthesis of the archaeology of the Southwest produced the first Pecos Conference in 1927 (Trigger 2004:188-189).

The Pecos Conference produced a classificatory scheme authored by Winifred and H. S. Gladwin. Their scheme used a hierarchical system to describe cultures based upon biological metaphor: roots, stems, branches and phases (Trigger 2004:189). "While the Gladwin … hierarchy was based on relative degrees of trait similarities, its dendritic pattern involved geographical considerations and it was implicitly chronological; roots formed before stems and stems before branches" (Trigger 2004:189-190). This was significant because "the system implies that the prehistoric cultures of the southwestern United States had become increasingly differentiated through time, which while a possibility was by no means demonstrated" (Trigger 2004:190; Willey and Sabloff 1980:105). E.B. Sayles (1935) used the Gladwin method to propose the term "Panhandle Phase" in his *Archaeological Survey of Texas.* Lintz (1984:326) noted that "Sayles was the first to employ an explicit taxonomic system" to define the distinctive traits of the Panhandle Phase, but that since few reports were published in the late 1930s and early 1940, the term was never widely adopted.

In an area of research crowded with interesting individuals, amateur archaeologist Floyd Studer was a leading figure in Texas Panhandle archaeology for most of his life (Rathjen 2008). Studer was a constant presence from the early 1900s until his death in 1966, escorting Holden, Mason, Sayles, Krieger, and many others to the sites (Krieger

1946:19). Studer carefully documented sites, but he encrypted his maps, lending some confusion as to proper provenience of artifacts, and in some cases, the actual location of sites (Indeck 2008). He kept secret his knowledge of the Alibates Quarries (Figure 1-1) for 35 years (Rathjen 2008). However, Studer mapped and documented over 200 archaeological sites in the area during his lifetime (Rathjen 2008).

In 1938, a turning point in the investigation of Antelope Creek archaeology was initiated by the Works Progress Administration (WPA). The WPA, created in 1936, funded a series of archaeological excavations throughout North America, including the Texas Panhandle (U.S. Department of State 2005:217-218). Two archaeologists hired in 1938 by the WPA, were Ele M. and Jewel A. Baker (Studer 1938). The husband and wife team conducted excavations at Antelope Creek Ruin Number 22 and Alibates Ruin Number 28 from 1938 through 1941 (Figure 1-1) (Baker and Baker 2000). Writing of the ongoing excavations at Antelope Creek Ruin Number 22, Studer, hired by the Panhandle-Plains Historical Museum, noted that approximately 500 artifacts had been recovered and that "a careful record was made as to position and depth of every artifact" (Studer 1938:4).

These records list approximate depths for each described artifact and the section (the Bakers' used the term "section" for an excavated unit) in which they were found. Resolution for artifact provenience is limited to a ten foot by ten foot area (the size of their "sections") at the designated depth. It is not known if the Bakers made compilation maps showing artifact proveniences or distributions; if so, they have not been found. As imprecise as these measurements might seem to a contemporary researcher, the Bakers' work was much more carefully executed than their predecessors' efforts. However, the

Bakers' report, in the form of their field reports, was not published for over 60 years (Baker and Baker 2000), and consists of description of data they collected, and is missing critical maps.

Studer's preliminary report (1938) contains some of the most interesting interpretations of the Bakers' data. In that report, he was the first person to suggest chert mining as an industry for what he called the "Texas Panhandle Culture Indians". He wrote that "dolomite flint mines indicate hundreds of tons were removed, not only for their own use but perhaps for trading purposes" (Studer 1938:4). Studer posited that some of Kidder's Pecos finds, artifacts made of brightly-colored dolomite, could have come from the Texas panhandle (Studer 1938:5). Of the lithic assemblage thus far recovered, Studer interpreted that limestone slabs were gathered for housing, that quartzite was exclusively used for manos, sandstone for "mutates" *(sic)* and "arrowhead polishers", and that agatized dolomite was used for arrow points, knives, scrapers, grooved axes and hammerstones (Studer 1938:5). He noted that the knives and projectiles were "decidedly better in workmanship than those of nomadic Plains Indians" (Studer 1938:5). Studer observed that the polished axes found at Antelope Creek Ruin Number 22 were made of a material that could have come from the Mississippi Valley (Studer 1938:5). He also noted the presence of Olivella and mussel shells he believed "indicated either trade relations with the cultures of the west or they were brought in from the South Pacific Coastal region in earlier times" (Studer 1938:5).

Bone tools were numerous, and were indicated as having been of "every type described by A.V. Kidder on the Pecos Pueblo" (Studer 1938:8). Studer described them as fleshing tools, scapula tools, notched ribs, large tubular decorated bones, antler tools, and weaving tools (Studer 1938:8).

Studer could see that the "wide mouthed, globular bodied vessels" found were "designed for culinary use" but that "no objects of art in pottery" were found (Studer 1938:5). He noted that while most Plains pottery was plain, varied little in functional design, and was seldom decorated other than with fingernail depressions, that the pottery of the Texas Panhandle Indians, while similar in design and function, rarely had a smooth exterior (Studer 1938:5). Studer recognized that a study of paste texture and composition was necessary in order to pin down the behaviors associated with recovered pottery (Studer 1938:5-6).

As with earlier projects, the Bakers' excavations focused mainly on architectural issues, carefully excavating the walls of structures, as well as hearths, benches and post holes, refuse piles, and storage cysts (Baker and Baker 2000). The Antelope Creek culture showed variation: right from the start, there were visible differences in Alibates Ruin Number 28 and Antelope Creek Ruin Number 22 architectural styles. At Alibates Ruin Number 28, the Bakers noted an additional platform on the west side of rooms, and Studer observed large window-like passages into adjoining rooms; both features not found at Antelope Creek Ruin Number 22 (Baker and Baker 2008:130; Studer 1938:8-9). Burials continued to confuse interpretation of the structures: the remains of eight people were found in one room (Studer 1938:8).

Excavation work in the panhandle virtually ceased after WPA funds ran out in 1941 when World War II began, but there was a desperate need for someone to interpret and synthesize all of the information gleaned from the region's archaeological record.

Alex Krieger was hired to oversee and summarize much of the materials excavated by WPA crews then archived at the Texas Archaeological Research Laboratory in Austin. Krieger's forte was as a lab-based analyst, and he was hired to make sense of the huge mass of work done during the WPA period. Calling it a "highly intriguing problem", Krieger attempted, for the first time, to reconcile of all of the research done in the Northern Texas region (Bousman 1974; Krieger 1946). In 1946, he published *Culture Complexes and Chronology in Northern Texas,* certainly one of his most significant contributions to Texas archaeology (Krieger 1946).

Alex Krieger was able to craft a synthesis of all of the WPA research by applying a system of cultural classification, taxonomy, to articulate a cultural history. While Sayles had used the Gladwin system to define the Panhandle phase and its traits (Lintz 1984:326; Sayles 1935), Krieger preferred the Midwestern Taxonomic Method, which "initiated systematic use of cultural units for classifying archaeological data in the United States" (Trigger 2004:191).

Though he refused to take credit for it, W. C. McKern will always be associated with the influential Midwestern Taxonomic Method first proposed in a workshop held in 1932 (McKern 1939:301, 1943:313; Trigger 2004:190). The Midwestern System emulates Carolus Linnaeus' biological classification system created in the 18th century, substituting family, genus and species with the Midwestern System's pattern, phase, aspect, and focus terms (McKern 1939). McKern termed the criteria for earlier classification systems as social and primarily linguistic, and suggested that archaeologists, when devising cultural classification, must avoid "hopeless" confusion by eschewing spatial and temporal factors (McKern 1939:302-303). In a 1943 reply to his critics, McKern suggested that archaeologists need to ignore and avoid arbitrary ethnological terminologies that relate more to psychology that archaeology (McKern 1943). He wrote that whereas archaeologists base their classifications only on recovered material culture (pottery seriation, lithic styles, etc.), ethnologists use culture, language, race and tradition, all factors that serve different purposes and solve different problems. In other words, he wrote, while ethnologists would write of a “Southwestern culture”, archaeologists would never use such a broad term, knowing instead that “culture” in the Southwest was neither as uniform or simple as the term suggests (McKern 1943:315).

Krieger defended his use of the McKern system in *Culture Complexes and Chronology in Northern Texas* by reflecting that even though critics, including McKern himself, doubted that the Midwestern System should be used for historical purposes, he believed that this was simply because no one had actually tried to do so (Krieger 1946:11). Krieger reasoned that when identical, or nearly identical, assemblages have been defined, researchers should follow the data, and place the foci in a chronological order. “It should matter little,” wrote Krieger, “whether these units are shown to be related in horizontal or in vertical (temporal) directions” and that there were no theoretical or practical limits on the manner in which foci could be used to show relationships or sequences (Krieger 1946:11). As such, he adopted the use of the Midwestern system for his study, with “no attempt to go beyond proposals for certain foci and aspects”, stating that the proposals “are not end-products of research, but merely organizational tools… helpful in that they allow one to refer summarily to aggregates of traits found in association, and to refer to a likely source for any specific trait which is at home in one aggregate but foreign to another” (Krieger 1946:12).

Krieger observed that while Antelope Creek sites exhibited an architecture that has some similarities to southwestern Pueblo and Plains styles, the "Texas Panhandle villages cannot be thought of as a peripheral Puebloan development" (Krieger 1946:73). There were simply not enough sherds of Puebloan pottery in the ruins for the Puebloans to have established the culture (Krieger 1946:73).

Krieger also noted that these villages had an "economic life, based jointly on agricultural and hunting" (Krieger 1946:73). To pursue this economy, Texas Panhandle village residents utilized a consistent artifact assemblage "of bone hoes, many artifacts of bone, antler and chipped stone, carved elbow pipes of stone, and the making of a single pottery ware, utilitarian and cordmarked" (Krieger 1946:73). These artifacts, wrote Krieger, "all point to affiliations with central Plains cultures" (Krieger 1946:73). "To attempt to classify Antelope Creek Focus as either a Plains or Puebloan culture is infeasible, for it was clearly a combination of both" (Krieger 1946:73).

Writing of the origins of Antelope Creek people, Krieger (1947:142) reiterated that they "represent a Plains bison-hunting and agricultural population basically very similar to Upper Republican, which wandered into the Canadian Valley". "Upper Republican" is a term used to describe a culture present in the loess plains of Nebraska and Kansas (Campbell 1976:6). Waldo Wedel agreed, commenting that "the Panhandle culture, as Krieger has suggested, looks like an Upper Republican complex with a modified form of Puebloan architecture" and that "it is not yet clear whether the physical relationships of the people were strongest with Plains, Southwestern, or other groups" (Wedel 1947:149-150). Prevailing thought at the time thus rested with a "northeasterly" origin for Antelope Creek peoples (Campbell 1969:13).

Though he designated an "Antelope Creek Focus", Krieger intended it to be but a starting point and noted that "there is reason to suspect that enough differentiations exists in material here, and in contiguous areas to provide, eventually, for the recognition of more than one specific complex" (Krieger 1946:41). Krieger's analysis only included the Antelope Creek focus and though he showed the culture to be only one of several variant cultures in the Panhandle region, he "did not perceive or include local variability or architectural differentiation between localities" (Krieger 1946:74; Lintz 1986:22). Krieger accepted the use of "Panhandle Aspect" to "include all the intimately related materials in the northern Texas Panhandle, together with whatever appears in neighboring areas (northeast New Mexico, southeast Colorado, western Oklahoma, etc.) to form a closely related series of foci" (Krieger 1946:41).

Phillips and Willey (1953:630) advocated the use of *phase* rather than *aspect,* as Krieger proposed, noting that the "focus", "aspect" and "component" terms used in the Midwestern Taxonomy are dependent on space and time for meaning. They write that "(t)he phase… is a formal abstraction that can be manipulated independently of space and time" (Phillips and Willey 1953:630). Bruce Trigger characterized all of the "phylogenetic" systems as "implying that native North Americans were imitative rather than creative"—these systems simply could not account for cultural change (Trigger 2004:194).

Trigger noted the failure of culture-historical approaches as used by most researchers as "a lack of will to discover, or even to search for any overall pattern or meaning" in the archaeological record (Trigger 2004:194). "Only a tiny portion of the most ambitious synthesis produced during the culture-historical period was devoted to interpreting rather than describing" that record (Trigger 2004:194). However, Bousman (2009) asserts that cultural historians asked only a narrow set of questions. Accordingly, they developed a restrictive methodology and limited set of epistemological rules to answer these questions— in other words, according to Bousman, culture historians may have failed to "explain", but they did a lot of interpreting of the archaeological record.

The Antelope Creek culture was subsequently referred to as a phase (Lintz 1986), and Krieger's scheme continues to be used as a cultural concept, despite its failure to explain observed variability across the region. The use of radiocarbon dating systems in the 1950s showed phases to be of longer duration and that, in some cases, they overlapped temporally and spatially (Phillips and Willey 1953:631). But Phillips and Willey presented no dates for Panhandle sites and theoretical positions regarding Antelope Creek culture did not significantly shift at this time.

Over the next few decades "numerous variants, aspects, phases, foci, and complexes [were] described for Plains Village cultural patterns in southeastern Colorado, Kansas, eastern New Mexico and northern and central Texas" (Brooks 1989:71). Brooks noted that researchers in this area had failed to consistently apply any taxonomic classification system and that only a few researchers across state lines had "adopted commonly accepted regional chronologies and taxonomic labels" (Brooks 1989:71).

The two decades after World War II generally saw a diminished intensity of field work on Antelope Creek sites, none reaching the scale of the Baker excavations. During this time, Krieger's influence was still felt, however, as the "cultural foundation defined on the basis of large continuous room structures" was "still in use, but substantially modified" (Lintz 1986:16).

Virginia Watson's research in the Oklahoma Panhandle at the Stamper site (Figure 1-1) was one such work influenced by Krieger. Indeed, Watson referred to her work as "supplementary" to Krieger's (Watson 1950:7). In her research analysis, she defined the Optima Focus, an "archaeological manifestation" she placed within the Panhandle Aspect and compared to both the Antelope Creek Focus and Upper Republican Aspect (Watson 1950:7, 52).

Watson's main argument for placing the culture within a different focus was the present of non-contiguous, single-structure buildings at the Stamper site (Watson 1950). However, Fred Schneider used a different excavation approach while excavating the Roy Smith (Figure 1-1) site, another supposed Optima site in the Oklahoma Panhandle, and was able to discern a multi-roomed structure, thus debunking Watson's hypothesis (Schneider 1969:172-173). Schneider (1969:174) pointed out that the major differences between the Roy Smith site and the Antelope Creek focus "is the greater proportion of decorated rim sherds, round lips, dart points, and corner-notched points not frequently found in Antelope Creek focus sites". He further noted that this discrepancy can be explained by the occupation of an earlier Upper Republican site in the area and that the variation "which exists in artifact types between the Smith site and the Antelope Creek focus is actually no greater that artifact differences which are found among the various sites of the Antelope Creek focus " (Schneider 1969:174). Schneider also criticized Baerreis and Bryson's contention (1966:109) that there are any temporal correlations between architectural styles within Panhandle aspect sites, noting that both single and multi-roomed structures occur in both "early" and "late" sites, and even occur in the same site on occasion (Schneider 1969:174).

Distinctions between the Optima focus in Oklahoma and the Antelope Creek focus in Texas continued to be made and referred-to through the 1970s, but was ultimately resolved by subsuming the Optima focus within the Antelope Creek phase (Brooks 1989:80; Duffield 1970:5, 21; Schneider 1969; Suhm & Jelks 1962). Explaining the variations observed in both lithic assemblages and architectural styles present at Panhandle ruins became the focus of most research in the region.

During the 1950s, Jack T. Hughes supervised excavations in the region as both Professor of Anthropology at West Texas State University and as paleontology curator at the Panhandle-Plains Historical Museum (Roper 1989:v). Hughes put great emphasis on excavation work, but published little (Lintz 1986:16). He used the term "Panhandle Aspect" instead of "Antelope Creek Focus," perhaps because he recognized the influence of other cultures, particularly Caddoan, variations that would make the broader "aspect" term a better fit (Hughes 1974). Hughes believed that there was "considerable circumstantial evidence to suggest that an Antelope Creek Focus strengthened" due to an increase in native populations, and these groups "may have constituted a final holdout of the Caddoan villagers on the High Plains until about the middle of the fifteenth century, when increasingly hostile relationships [and] less sedentary trading, together with raiding Apache immigrants forced a withdrawal to join other Plains Caddoan relatives in fortified villages on the Arkansas and Platte" rivers (Hughes 1974, 1991:33).

Lathel Duffield, in his 1970 study of vertebrate paleoecology on Panhandle aspect sites, commented that more large bones were found at the Alibates Ruin Number 28 site than at any of the region's sites he analyzed (Duffield 1970:96-97). Though he observed over 31 species of animal remains from the site, mammals composed over 91% of these— overall, bison remains were the most prevalent representations in the assemblage (Duffield 1970:95). Though he admits that more studies of faunal remains from surrounding sites need to be made, Duffield concluded that the area was subject to severe "desiccation" from 1250 to 1400 A.D. due to what he sees as an increase in antelope remains and a decrease in bison remains over this time period. This data coincides with conclusions made by Baerreis and Bryson (1965, 1966) that the Southern and Central Plains suffered from extensive periods of drought during this time period. However, Katherine Spielmann (1982:288) caution that the use of faunal samples not collected systematically could lead to false conclusions in characterizing diet from archaeological remains.

Other than undocumented and often perfunctory quarry excavations performed by Studer, and a few articles (mentioned earlier), the quarries themselves have received little attention from archaeologists. Bousman (1974) cited surveys done by the National Park Service (in particular, those done by Cal Cummings), and there is one known survey done by Susanna and Paul Katz, but it remains unpublished (Katz and Katz 1998, 2003). Bousman (1974:10) wrote that the majority of articles published about the Alibates Quarries "emphasize how little is known about the quarries and that reliable data are required about the quarries for a proper understanding of man's utilization of the quarries." A comprehensive map available of quarry pit locations within the boundaries of the Alibates Flint Quarries National Monument has not existed; however, that is one objective of this current thesis.

On August 31, 1965, President Lyndon B. Johnson authorized the establishment of Alibates Flint Quarries and Texas Panhandle Pueblo Culture National Monument. This was later shortened to Alibates Flint Quarries National Monument in 1978. This site incorporates both the quarry area and several ruins, including Alibates Ruin Number 28 and Alibates Ruin Number 28A, a small clustered site also partially excavated by the Bakers during their tenure with the WPA (Figure 1-1) (Baker and Baker 2000).

In the 1960s and 70s research centered on the origins of the Antelope Creek Focus and on further explaining all of the variation observed in recovered lithic, ceramic and architectural material. Most of the research debated over whether the Antelope Creek people migrated from either southeastern Colorado (Apishapa culture) or from Nebraska, Kansas or western Oklahoma (Upper Republican) into the Texas Panhandle.

First described by E.B. Renaud in 1931 during archaeological surveys of Apishapa Canyon in southeastern Colorado, the ruins he found there were considered to be "ceremonial in function" (Gunnerson 1989; Renaud 1931). Arnold Wither (1954) proposed the "Apishapa focus" as a taxonomic description of this culture. He also noted similarities between characteristics of the Apishapa Focus sites to Upper Republican Aspect sites, including the use of upstanding stones in architectural constructions, and similarities in pottery and projectile points recovered at both types of sites (Withers 1954). Withers also dated the sites based on "intrusive Southwestern pottery" from which "we may date the Apishapa Focus at about 1300 A.D." (Withers 1954:3). After examining of over 100 archaeological sites in the region, Robert Campbell (1969:iii-iv, 429-440) saw the influence of Apishapa culture in Antelope Creek Focus architectural assemblages, particularly in the elements of contiguous rectangular rooms.

Campbell posited that hunter-gatherer groups migrated out of southeastern Colorado down into the Southern Plains sometime during the Late Woodland period

(A.D. 200-1000). He also saw a similarity in lithic technology and cord-marked pottery types between Apishapa and Upper Republican, and later Antelope Creek Focus styles. Campbell wrote of an interaction between Apishapa and Upper Republican peoples as influencing, thus possibly originating the Antelope Creek Focus. He also elaborated on possible exchange routes between the Southern Plains and the southwestern Pueblo areas (Campbell 1969, 1976).

In the late 1970s, research on Antelope Creek sites became the focus of Christopher Lintz's dissertation. Lintz, taking a distinctly historical approach in his doctoral dissertation, examined and synthesized anew all of the previous research in the region. Lintz sought to "define the "range of morphological variation represented in the architecture and the spatial patterning of structure remains" and created a distinct typology for Antelope Creek architectural forms (Lintz 1986:85). According to Brooks (1989:80), Lintz attributed variability in the observed architectural forms to "functional differences, engineering constraints, and changes in design over time".

Lintz refers to the late prehistoric cultures which manifested this region as "The Upper Canark Variant" (named for the upper Canadian and Arkansas River valleys), with Antelope Creek being but one phase (Lintz 1986:25). James Gunnerson (1986:128) notes that Lintz "is not explicit as to what Upper Canark is a variant of", but that, "by implication it would be a regional variant of the Plains Village pattern" and that "presumably Apishapa and Antelope Creek had parallel developments". Lintz subdivided the Upper Canark variant into two distinct phases: the Apishapa, first postulated by Campbell (1969), and the Antelope Creek Phase (Lintz 1986:25). Brooks (1989:80) posits that analysis problems still remain and will continue to remain until distinctions are understood in "architecture, material culture, and subsistence practices between the Buried City complex, the Apishapa Phase, and the Antelope Creek Phase".

Lintz published over 50 radiocarbon dates from 16 Antelope Creek sites which redefined the temporal range from approximately A.D. 1200 to A.D. 1500 (Lintz 1986). He also compiled 22 radiocarbon dates from 17 Apishapa sites and identified a chronology of A.D. 940 to A.D. 1390. These show the Apishapa Phase as occurring and overlapping the early portion of the Antelope Creek Phase (Brooks 1989:80; Lintz 1986). This contrasted with Hughes' (1974) speculation that the Upper Canark peoples developed locally out of Plains Woodland and eventually abandoned the region "to join their Upper Republican relatives, evolving into Lower Loup and Pawnee in Nebraska" (Brooks 1989:80). Gunnerson (1989:128) proposed that "perhaps the Apishapa people joined with the Upper Republican people in their exodus from the Central Plains" "triggered by the severe droughts of the 1300s and 1400s."

Accepting Baerreis and Bryson's (1965, 1969) regional environmental history, Lintz suggested that the Antelope Creek people began to live in isolated homesteads as a "buffering mechanism", a response to worsening environmental conditions that made living in groups difficult (Lintz 1986:237, 251, 252). He wrote that cultural dynamics created a demand for food that exceeded the carrying capacity of the land (Lintz 1986:253).

The results of excavations at, and around Landergin Mesa in 1984, supervised by Christopher Lintz and Robert Mallouf, began to hint that isolated homesteads were as common as contiguous rooms. There was evidence that there were times of conflict when people retreated to defensible positions (Lintz 1986:50).

Scott Brosowske (2005) investigated the origins of exchange practices in the Southern High Plains and made inferences about the economic practices of the Antelope Creek Phase. In his dissertation, Brosowske (2005:2) referred to the time from A.D. 1200- 1500 as the Middle Ceramic Period, when sedentary to semi-sedentary populations practiced a mixed economy of foraging, hunting and horticulture. He noted that trade and exchange in the Southern High Plains was "essentially nonexistent" during what he called the Early Ceramic period (A.D. 500- 1200), but that exchange of items, particularly related to subsistence, began after A.D. 1200. He further remarked that 80-90% of chipped stone objects in the Southern High Plains were imported from sources 100 to 300 km distant (Brosowske 2005:2). Brosowske found that prestige items, having been obtained from as much as 600 km distance were much less common and are present in extremely low quantities in Southern High Plains settlements. However, numerous exotic items were recovered from three Antelope Creek settlements: Alibates Ruins Number 28, Chimney Rock Ruins 51, and Odessa Yates (Figure 1-1) (Brosowske 2005:3). Brosowske suggested that these communities were capable of producing a surplus of products such as chipped stone tools, bison hides and dried meat for use in inter-societal exchange (Brosowske 2005:288-291). He created models that showed exchange "as an activity that expanded incrementally to procure objects at greater and greater distances" (Brosowske 2005:6).

The notion of specialized production and intensity of production are critical to Brosowske's discussion of Antelope Creek community life. Cathy Costin (1991, 2000) lays out strategies, and their pitfalls, for inferring craft specialization and the organization of production in archaeological contexts. She describes four parameters of production:

context, concentration, scale, and intensity (Costin 1991). These parameters can be identified in the archaeological record by examining and identifying differential distribution of debris, tools, and facilities associated with production. She cautions that, when creating general models of production, a researcher should look across an array of crafts, not just at ceramics. When looking at ethnographic studies, an archaeologist must understand that not all activities represented by the ethnographic present were practiced by those who lived in the past.

Costin (1991) points out that specialization and production are not the same thing. Specialization is defined as a situation wherein there are fewer producers of an item than there are consumers of that item. Production involves the transformation of raw materials into useable objects. An investigation into either of these areas will entail a different strategy for each. She notes that "specialization is a differentiated, regularized, permanent, and perhaps institutionalized production system in which producers depend on extra-household exchange relationships at least in-part for their livelihood, and consumers depend on them for the acquisition of goods they do not produce themselves" (Costin 1991:4).

Identifying why production was specialized, what constitutes production units, the intensity of production and its locus of control, as well as the identity of the artisans, are critical foci of inquiry for the archaeologist. She criticizes research that focuses on alienation of labor, Marxist analyses, due to the lack of distinction between elite and general demand—implying that the notion of attached specialization develops as part of a political process, while independent specialization evolves to meet utilitarian needs (Costin 2000). Costin believes that part of the problem with production and distribution research, in general, is a lack of accepted definition of terms. Expanding the traditional four categories, Costin proposes an eight-part typology for the organization of specialization. Identification of specialization involves also identifying the four previously mentioned parameters of production in the field, not always a straightforward task. Archaeologists have three basic types of data available: "the objects themselves (and their material, technological, and stylistic attributes), the debris from production activities, and the physical contexts from which the objects and debris were recovered" (Costin 2000:378-379). It is from these data that archaeologists make all of their inferences about the assemblage and the location of production, following up with reconstructions of how production was organized.

Intensity is the most difficult factor for the archaeologist to tease out of archaeological remains. Costin argues that relative density of debris can fool an archaeologist into inferring full-time production, for example, without having reliable data on the actual amount of debris a process might generate. The number of workers involved is an important part of this idea; however, there is seldom any indication of this number to be found. The author suggests that the best way to identify intensity is to identify the entire range of economic activities in which a household of individual is involved (Costin 2000). This, she says, involves little more than looking at the range of recovered tools used in those activities. Indirect evidence is sometimes the best indicator of activities. Costin further states, that even recognizing compositional patterning involves tossing out the idea that workshops were solely economic, social, or political units— she says that they were clearly all of these things. She suggests that only broad, comparative studies will resolve these issues, and that ethnoarchaeologists need to provide more of this kind of study. Without complimentary and contextual data, the "specific organizing principles of the groups identified through materials analysis may not be known fully by archaeologists" (Costin 2000:387).

Brosowske defined both direct and indirect forms of evidence for specialized production (Brosowske 2005:291). Direct evidence for specialized production included facilities associated with production "as well as variability in the distribution of raw and waste materials, tools, and finished items" within the context of households, settlements, social classes or time periods" (Brosowske 2005:291). Brosowske also inferred specialized production from indirect evidence such as the presence of large numbers of items which are highly standardized or require a great deal of manufacturing skill (Brosowske 2005:291). "Variation in the spatial distribution of objects with these characteristics is often used to infer, albeit indirectly, the presence of specialized systems" (Brosowske 2005:292). Brosowske examined lithic materials recovered from Antelope Creek settlements in both Texas and Oklahoma and concluded that the inhabitants of Alibates Ruins Number 28 and other communities near the quarries were part-time craft specialists producing stone tools for export (Brosowske 2005:293).

Based on the fact that 24 residential structures were excavated at the Alibates Ruins (Alibates Ruin Numbers 28, 28A and 30) (Figure 1-1), Brosowske suggested that as many as 24 families resided there, with a total of 40-50 families living in the immediate area around the quarries; enough people to have provided the labor and organization necessary for specialized lithic production (Brosowske 2005:294). Brosowske, however, is making a logical inference rather than substantiating it with any ethnographic evidence. He also noted that the increased flow of subsistence-related objects allowed for the people to gain skills to organize long-distance expeditions and exchange networks (Brosowske 2005:399). These skills served to provide "the leverage needed to manipulate economic, social, and ideological systems" (Brosowske 2005:399). Brosowske proposed that the economic trends he documented would have required leadership and organization, a much more complex picture of life in a hunter-gather, semi-sedentary society than had been described previously (Brosowske 2005:399). Unfortunately, Brosowske made no claims as to the ultimate disposition of Antelope Creek societies, why they abandoned their sites and why their economy failed.

That warfare and violence was present has been mentioned earlier. There seems to have been defensive reasons for occupying Landergin Mesa and it undoubtedly played a role in the disposition of Antelope Creek society (Brooks 1994; Lintz 1986). "There is evidence for a *moderate* level of conflict during this period in the Texas panhandle. However it is unclear whether this represents a pervasive pattern or infrequent occurrences" (Brooks 1994:38).

Other recent studies (Huhnke 2001; Meier 2007; Weinstein 2005) , illuminate even as they further complicate our picture of Antelope Creek peoples. Marie H. Huhnke compared use-wear patterns and polishes present on bison scapulae and tibias assumed to have been used as hoes and "digging-sticks" (Huhnke 2001). Much to her surprise, the evidence for use-wear differs between tools. The tibia showed wear patterns expected when used for digging and other such assigned agricultural tasks (Huhnke 2001:55-58). The wear patterns exhibited on the scapulae, however, indicated that they were more likely to have been the result of use as tools to spread mortar rather than as agricultural hoes (Huhnke 2001:55-58).

In 2004, Bousman began an extended excavation program at the Cross Bar Ranch. Two MA theses were conducted and others are in progress based on that project (Meier 2007; Weinstein 2005). The first of those theses consists of the analysis of the first season's excavation data from 41PT109 (Figure 1-1), an isolated Antelope Creek homestead (about 25 miles SW of Alibates Ruin Number 28) by Abby Weinstein (2005). Weinstein (2005) revealed an assemblage composed of artifacts, small and broken, and no presence of burned daub. Weinstein suggested this implied "that the site was left as part of a *planned* abandonment" (emphasis, this writer), for reasons still unclear (Weinstein 2005:118).

Holly Meier (2007) examined pottery sherds from Landergin Mesa, Alibates Ruin Number 28, and 41PT109 using Instrumental Neutron Activation Analysis (INAA). Although she evaluated only a small sample of sherds, Meier found an interesting and unexpected pattern of movement of local and exotic materials. Meier had originally posited that "the variation of ceramics would be greatest at larger sites… due to the influx of cultivated foods carried… from the smaller sites to the larger ones" (Meier 2007:61). Instead, the tests indicated that there was greater variety present at the smaller 41PT109 isolated site (Meier 2007:62). Lintz (1989) has suggested that aggregate sites were occupied earlier than the isolated sites, yet, Meier (Meier 2007:62) stated that her data implies "that the three sites are not as contemporary as their radiocarbon dates suggest". She admitted that "Landergin Mesa (A.D. 1250-1380) and Alibates Ruin Number 28 (A.D. 1340-1410), may overlap, but the single radiocarbon assay dating 41PT109 may be a misleading date" (Meier 2007:62). Meier further commented that her sample was small and that further investigation will be necessary to fully understand the interactions within Antelope Creek society (Meier 2007:63).

More questions remain unanswered than answered with regard to Antelope Creek. It is certain that the Antelope Creek peoples engaged in mining and trade of Alibates flint, but it is still uncertain how they were organized as a society(s) or what type of ideology(s) they followed. In addition, we still cannot be certain of the origin and the ultimate disposition of the Antelope Creek peoples: we do not know where they went, or why.

CHAPTER III

OVERVIEW OF LITHIC PROCUREMENT AND OF MINING AND QUARRY RESEARCH

Though mining is the targeted focus of this paper, not all chert was acquired through mining. It is, therefore informative to review what is known about lithic procurement systems and examine what observations in the archaeological material record would possibly dispute these ideas. After an examination of procurement strategies, an overview of mining and quarry research will be presented, ultimately focusing on the Alibates Flint Quarries National Monument and the main research focus of this paper.

Lithics: Direct Procurement. There are two types of direct procurement strategies, one in which logistically organized task groups regularly collect lithic materials on trips regularly organized for this purpose, and one in which an individual or individuals embed lithic procurement within other tasks (Binford 1979:259-260, 1980:10). These are not mutually exclusive strategies, but they would leave significantly different assemblages and distributions of material remains. Discovery of evidence of procurement intensification strategies, such as caching of hammerstones or stockpiling raw materials in bulk, could imply that either a foraging group or a specialized group returned regularly to a particular place to collect lithic materials: in other words, regular exploitation equals intensification. Concentrations of flakes from different production stages at acquisition sites might also suggest an organized task group activity, but not in all cases.

Binford (1979, 1980) suggests that the frequency of the occurrence of certain tools in habitations is directly related to general subsistence procurement activities, while Gould and Saggers (1985) suggest that distance from the source plays more of a role in this kind of direct acquisition assessment. Because this paper is concerned with not only quarrying behaviors, but also with settlements that were very close to abundant lithic sources, this discussion will center on Binford's analysis. Therefore, an analysis of the frequency of tools used in knapping and quarrying activities found in habitation sites and/or at acquisition sites would be most informative (Binford 1980:10). Binford assumed that specificity and specialization in a procurement strategy would result in sites not only organized by general logistics, but would also be generated "with respect to specific types of target resources" (Binford 1980:10). Binford is also assuming that production would consist of standardized production of only a few tool classes, a view also shared by Shafer and Hester (1991).

Also relevant to procurement and reduction strategy analysis would be the distribution of flakes and cores across a foraging area (Binford 1980). The types of flakes, as measured by the amount of cortex on flakes, recovered from habitation areas could also reveal much about local procurement. The first indication that individuals were not collecting lithic materials informally with embedded strategies would be the presence at sites of large mounds of chert debitage (Shafer and Hester 1991:81).

Though small-scale mining is an activity that can be accomplished by individuals, large-scale mining is more the focus of this paper, and it is most often a labor-intensive activity involving scheduling, coordination and management of a group of people, perhaps dedicated specialists. A study of workshop areas either near/at mines or within and around habitation areas could be instrumental in determining the types and quantities of tools produced (Shafer and Hester 1991). The presence of mining activities could indicate indirect, intra-group exchange practices or the intensification of exchange. Examination of debitage deposits could indicate the level of production both at habitation (village) sites and mines to determine if production of tools exceeded estimated local need. Also relevant is the possible presence of craft-- in this case, lithic specialists. Jeanne Arnold (1984:37) defined five diagnostic indicators of craft specialization that could be observed at archaeological sites:

1. a high relative and absolute volume of stone tool production;
2. a certain kind and degree of standardization in tool production methods;
3. repeated and intense use of well-defined activity areas (craft workshops) within a site or sites;
4. evidence for some degree of control over critical stone (e.g., quarries, and;
5. the presence of specialist paraphernalia with certain burials.

Of course Arnold (1984:37) explained that not all of these criteria need to be present at a site, and that these criteria should not be "construed as constituting absolute proof" of specialization, but must be evaluated on a case-by-case basis. Arnold also notes that craft specialization most frequently occurs in societies at "institutional" (as organized by political, or elite establishments), or "guild" level (associations of craftsmen only). Even though there is a lack of centralized power for underwriting these activities in band or tribal societies, she notes that some forms of incipient specializations do exist within them, and that they tend to be "more variable through time and space and smaller in scale" (Arnold 1984:38).

Shafer and Hester (1991) determined that lithic craft specialization took place at the Maya city of Colha in Belize. They found that these craft specialists produced far more of four specific tools (oval bifaces, general utility bifaces, stemmed macroblades and eccentrics) than could be consumed by the local population. Furthermore, Shafer and Hester (1991:94) found that while these tool types were recovered in the remains of sites in the surrounding area, what they called "consumer sites," there was no evidence for formal tool production at those locations, "at least not to the extent or degree that would account for the rates of formal tool consumption at those sites". The workshops at Colha seem to have expanded along with an increase of population and intensification of agriculture in the area (Shafer and Hester 1991:92). Tools produced at the workshops were both utilitarian and non-utilitarian, with utilitarian tools distributed in highest frequency in the immediate region (Shafer and Hester 1991:94). Non-utilitarian tools were distributed farther into what Shafer and Hester called the "peripheral consumer area" (Shafer and Hester 1991:94). Interestingly, Shafer and Hester (1991:94) could find no evidence that the craft specialists were directed by an elite or ruling class, but that instead, tools were produced for the benefit and/or profit of the craft producers themselves.

Lithics: Indirect Procurement. Indirect procurement of lithic materials can involve either intra- or inter- group exchange schemes, or both in some unknown combination (Binford 1980; Polanyi 1957). Intra-group exchanges occur within groups, perhaps between neighbors, or involve acquiring lithic material from the local specialist. These exchanges are generally either positive or balanced reciprocity exchanges (Polanyi 1957:243-270). While it is possible that status differentiation occurred within the political structure of Antelope Creek society, empirical evidence has not yet been found that would eliminate it as an egalitarian community (Brosowske 2005:360). Brosowske (2005) suggests that similar types of societies found elsewhere have been called "tribal, nonstratified, middle-range, nonhierarchical, or transegalitarian." Though a number of burials from the area have been studied, no clear variation in mortuary patterns has been perceived by researchers (Lintz 1986:164). Lintz (1986) noted that what burial goods were present indicated positions in society that may have been ascribed, or inherited, but that these positions were not rank-, or status-related . Here "rank" is by formal or political hierarchy, while "status" could be acquired by wealth or some other social practice. Since some trade jewelry and artifacts were found in the internments of women, Lintz (1986:174-176) interpreted this to mean that Antelope Creek society was egalitarian with a matrilineal-centered rule of descent. Habicht-Mauche and her colleagues (1994:301) examined the skeletal remains of 29 individuals recovered from Antelope Creek contexts and concluded that there was a significant shift in diet toward plant foods that might indicate either an intensification of agricultural pursuits or indicate increasing trade with neighboring horticultural groups, both of which would indicate an increasingly complex societal structure. Hard et al. (1996) iterated three data classes by which maize dependency might better be estimated: the comparing of stable carbon isotope, macrofloral and ground stone sets from a variety of regions and time periods-- all need to be taken into account. They noted that simply looking at any one of them, such as Habicht-Mauche et al. (1994) had done, overlooked a large variation in agricultural development.. Hard and his colleagues articulated how best to take into account formation processes and linking arguments in order to gain a higher resolution of the adoption of agriculture in the Southwest. These arguments complicate the identification of how social structure developed in agricultural regions. Overall, Antelope Creek activities likely created a need for higher levels of complexity and "logical cohesiveness" than would normally be seen in hunter-gatherer groups (Binford 1980; Brooks 1994:38; Lintz 1986).

Redistribution procurement is an internal exchange scheme. It takes place within societies that have a central authority such as chiefdoms and states. In redistribution scenarios, goods (foodstuffs, raw materials, tributes) are collected and sent to the central authority, which then redistributes it within the range of authority (Sahlins 1979:262).

It is also possible to obtain lithic materials from a source outside the group, perhaps from craft specialists (in this case, miners) who reside in nearby villages or hamlets (Shafer and Hester 1991:79) or dedicated traders. In small-scale agricultural societies inter-group relationships are formed, usually through matrilineal lines (Brosowske 2005:359-361), which could have included the exchange of lithic materials. Kin groups involved in mate exchange might have accepted lithic materials as payment for a bride. Lithic exchange also could have taken place as part of a risk-reduction plan (Sahlins 1972:307; Wiessner 1982:173). These kinds of exchanges are more problematic to interpret from archaeological remains. As exchanges take place, materials shift in meaning and value, making their place in the archaeological record difficult to observe and record properly (Lintz 1984:164). It is reasonable to assume that supply of Alibates materials would diminish as distance down-the-line from the site increases; therefore it follows that the value of the material might increase with distance and scarcity (Polanyi 1957). Eventually, certain materials become perceived as valuable enough to create a larger external-than-internal demand for them. A craft specialization might emerge within individual hamlets or villages. These communities might skew their labor force toward creation of more materials for trade (Shafer and Hester 1991). Areas of intensification and craft specialization can be interpreted from the archaeological record (Binford 1980; Shafer and Hester 1991). There is no published evidence that raw materials were stored centrally at Antelope Creek aggregate sites, but there has been no thorough study of contents of some rooms termed as "storage" at major sites (Baker and Baker 2000; Brooks 1994, 2004; Hughes 1991; Lintz 1986). Market exchange procurement involves a central location where traders engage in price negotiation and price fixing: a market system. This kind of trade is associated with larger societies, and would involve exportation of Alibates material to larger markets.

Overview of Chert Mine and Quarry Research

Mining could be considered one of the oldest human industries, and is at the heart of all human developments—it is a basic economic activity that provided the means for producing food, clothing and shelter (Holgate 1991; Holmes 1919; Luedtke 1984; Shepherd 1980; Singer 1984). However, "when we consider the wealth of information on the varieties of human experience, our information on the activities at quarries and workshops ranks among the most abysmal" (Ericson 1984:8), and publications on the topic are under-represented in the North American archaeological literature but better known in Europe (Singer 1984).

At its beginning, chert quarry research in America was largely inspired by events happening in nineteenth century Europe, particularly in England and France, surrounding the antiquity of man. Discoveries of artifacts in-situ with the remains of extinct mammals in France, set off a firestorm of activities in Europe intended to locate similar such artifacts and remains.

Quarry Sites in Britain

The majority of flint seams in the United Kingdom (UK) occur within thick Cretaceous chalk deposits in southern and southeastern England and therefore, most of the studied ancient flint quarries are within that region (Barber et al. 1999; Holgate 1991; Shepherd 1980). Many of these sites had been known of for centuries, but were not recognized as mines until the late 1860s (Barber et al. 1999; Holgate 1991; Russell 2000). For clarity and convenience this paper will be focus on Grimes Graves and Cissbury, the most extensive flint mining sites in the UK. Excavations conducted at both of these locations are considered among the earliest formal archaeological investigations in Britain (Holgate 1991). Today, more is understood about Cissbury and Grimes Graves, than about all of the other quarries in the UK (Barber et al. 1999; Holgate 1991; Russell 2000).

Known since the sixteenth century, "Grimmers", or Grimes Graves ("graves" being local jargon for a pit, and does not refer to burials) covers 93 acres and contains

433 depressions and features: for three hundred years it was described as a set of fortifications or as a "very curious Danish encampment in semi-circular form" (Barber et al. 1999; Russell 2000; Shepherd 1980:53-54). Cissbury, in Sussex, is the home of a famous Iron Age fort. Prior to any excavation, the 270 recorded pits and depressions found there were also interpreted as fortifications (Barber et al. 1999; Shepherd 1980).

In the UK, flint is mostly found in the southeastern portion of the island, in the remains of the formerly massive Cretaceous chalk deposit that was the result of sea bed sediment deposition between 144 and 65 million years ago (Barber et al. 1999). Isotropic rock such as flint occurs in seams that vary widely in thickness, and are usually conformably bedded in conformity within the limestone strata (Shepherd 1980:7). Depending upon the degree of tilting, a seam may occur at any angle from level to nearly vertical (Shepherd 1980:7). Though flint occasionally occurs in other matrices, such as clays or secondary gravels, there is no evidence that these nodules were ever quarried (Barber et al. 1999).

In 1868, while researching hillforts, Colonel Augustus Lane Fox (later known as General Pitt Rivers), correctly identified the pits he was excavating at Cissbury as being filled-in ancient flint quarries (Barber et al. 1999; Holgate 1991; Lane Fox 1869, 1876; Russell 2000). Since he did not excavate all of the chalk infill from the pits, Fox never claimed to have seen any flint seams, but he was the first to discover that they led to a network of galleries (Barber et al. 1999; Lane Fox 1869, 1876). Canon Greenwell undertook a major excavation at Grimes Graves from 1869-1870 (Greenwell 1870). Overseeing the excavation of one shaft to a depth of over 12 meters (39 feet), he uncovered and partially explored a series of galleries that radiated off of the main shaft.

Greenwell noted that flint was present in at least three vertically segregated seams (Greenwell 1870). Denoting the seams as "topstone," "wallstone," and "floorstone," Greenwell also noticed that it was the latter which received the most attention from the ancient miners, and that even "modern" gunflint makers preferred the same materials (Greenwell 1870:423). Greenwell found the bones of domesticated animals in the pit shaft and galleries and concluded that the site was Neolithic (Greenwell 1870). He observed that the infill he was excavating out of the shaft was "chalk and sand taken out of other pits" (Greenwell 1870:422-423). He also noted that while some of the recovered lithic artifacts resembled Paleolithic era specimens (a minor comment that would bedevil researchers for more than 50 years hence), other evidence pointed to Neolithic origins for the artifacts (Greenwell 1870; Mercer 1981a). Other excavators also noted that the miners had a definite preference for the floorstone over the shallower seams (Barber et al. 1999; Lane Fox 1876; Holgate 1991; Russell 2000). The top two seams of flint are described as being composed of "weathered nodular flint", while the preferred floorstone is noted as being composed of "large tabular nodules approximately 15cm in thickness with a heavy cortex on its base" (Mercer 1981a). Researchers discovered that the deep pits contained complexes of galleries that frequently radiated off of the main shaft in every direction (Barber et al. 1999; Clark and Piggott 1933; Greenwell 1870; Holgate 1991; Lane Fox 1876; Mercer 1981a; Peake 1915; Russell 2000; Shepherd 1980). In addition, they found that obvious and shallow outcrops of flint were mined through the use of shallow pits that at times became bell-shaped due to undercutting into flint seams (Barber et al. 1999; Clark and Piggott 1933; Greenwell 1870; Holgate 1991; Lane Fox 1876; Peake 1915; Russell 2000; Shepherd 1980).

Despite the fact that Greenwell had provided evidence of the site's age to be Neolithic, in 1912 and 1914 Reginald Smith and A. K. Peake both published articles that likened tools found at the site to artifacts found in context with extinct animals (Holgate 1991; Peake 1915). Smith, had written, in 1912, of his belief that the pits were "Mousterio-Levalloisan" in age— writing in Peake's report, he reiterates this contention (Smith 1912; Peake 1915). Smith did no real debitage analysis, but did recognize two types of work areas at Grimes Graves: areas containing "massive chipped pieces" and areas containing "both massive pieces and minute flakes" (Holgate 1991; Peake 1915). In 1914, Peake had found open pits as well as galleried and un-galleried shafts. He assumed that the "primitive non-galleried units" were the oldest means of extraction (Clark and Piggott 1933; Peake 1915). It was not until 1933 when Grahame Clark and Stuart Piggott published the results of their own investigations and reviewed the past 60 years of excavations, that the Paleolithic dating of the quarries was refuted (Clark and Piggott 1933). They agreed with Greenwell's observations and provided their own stratigraphic evidence that pottery and other artifacts found in-situ were Neolithic in age.

By the 1940s, it was accepted that a majority of discovered quarries were most utilized during the Neolithic (Russell 2000; Shepherd 1980). Radiocarbon dating in the 1950s provided more definitive evidence that the quarries were Neolithic in age ranging from 3500-2000 B.C. (Barber et al. 1999; Holgate 1991). Research activity at British prehistoric mines came to a halt for nearly 20 years, until 1971, when, R. J. Mercer directed a project that included the refurbishment of one pit left open for the public to view, and the excavation of another shaft (Mercer 1981a, 1981b). G. G. Sieveking's 1972 radiocarbon dating tests indicated that at Grimes Graves, the oldest pits were in fact, the deepest ones (Sieveking et al. 1973). Sieveking and his colleagues noted that the prehistoric flint miners camped on or near the mines and found evidence of Neolithic and early Bronze Age artifacts in the shallower pits (Sieveking et al. 1973:193). It was also assumed that the quarries were the primary source of stone axes.

Further investigations and radiocarbon dating of artifacts recovered at Grimes Graves and other British quarry sites have revealed that though there was activity at the quarries for over 1000 years, and that they were *intensely* worked an average of 300 of those years (Holgate 1991; Mercer 1981a). Clark and Piggott (1933:181-182) noted that it was the character of the local geology that determined mining technique—safety, and particularly expediency, determined how flint was quarried.

Tool marks were observed undisturbed on the walls of some pits, and discarded tools were frequently found in the shafts and pits (Clark and Piggott 1933; Holgate 1991; Shepherd 1980). The main tools used for mining were the shed antlers of red deer, likely gathered during the winter—tools similar to those found at quarries in France and elsewhere around Europe (Clark and Piggott 1933; Holgate 1991). All of the tines were removed except for one, which was used as the pick tip (Clark and Piggott 1933; Greenwell 1870; Holgate 1991; Lane Fox 1876; Shepherd 1980). At Grimes Graves there is evidence that stone or flint axes, mounted in wooden handles, were also occasionally used (Holgate 1991). Researchers recovered over 570 deer antler picks from the fill of four shafts at Grimes Graves, and calculated that the total number represented at the site would likely have been 40,000, representing 24,000 male deer (Holgate 1991). Scapulae "shovels" were also found in small numbers in English and French mines (Holgate 1991). Shepherd (1980:33) makes note of an experimental project done in 1960 that used antler and scapula tools for quarrying work. Researchers discovered that while the antler tools worked well, scapula tools were unsuited for the actual mining, and worked well only for scooping refuse together when cleaning out a floor (Shepherd 1980). The over 40,000 tons of flint estimated mined at the Grimes Graves would have been made into an astounding 25 to 30 million implements (Holgate 1991:45).

At Grimes Graves and Cissbury, it is apparent that mining probably began along the edges of the sites, where the flint appeared in outcrops (Russell 2000:65-75). Un-weathered walls suggest that pits were backfilled quite soon after their use (Clark and Piggott 1933).

Gale de G. Sieveking et al. (1973:183) note that until their effort, there had been no single accurate survey of a flint mine and lament that all previous researchers have done was to create an inadequate description of the general character of flint mines. All their predecessors did was to "extrapolate a general picture of large-scale sites" from the results of the excavations of but one or two shafts or pits.

Research at the mines eventually focused on the distribution of flint axes across Britain. Axes were grouped by stone type in order to investigate exchange patterns: a technique used for over 50 years, but not seriously referred to in broader studies until the late 1970s (Barber 1999:15; Bradley and Edmonds 1993; Grimes 1979; Purdy 1984). The development of implement petrology moved archaeology away from a strictly "collector's approach" that was concerned mostly with objects considered valuable in their own right: artifacts were never subjected to destructive testing (Grimes 1979:1). Axes and collected flint samples were subjected to petrochemical and geochemical analysis; however this line of research has since proven to be frustrating for the identification of sources of specific types of stone (Bush and Sieveking 1979; Grimes 1979).

The American Paleolithic "Problem" and the beginnings of quarry research in the United States

Because it was geology that seemed to pinpoint the chronology of the European artifacts, the Smithsonian Institution's 1861 Annual Report included a geologist, George Gibbs, who directed the proper "Instructions for Archaeological Investigations in the United States" (Gibbs 1862:392). Gibbs expressed specific interest in "those articles found under conditions which connect archaeology with geology," particularly, "implements of the same description found in deposits of sand and gravel or other like material exposed in bluffs or steep banks, such as have recently attracted the attention of European geologists" (Gibbs 1862:395).

Most geologists and archaeologists believed that a single, uniform geology existed across the globe. They were certain that evidence of the same antiquity of humans as seen in Europe would surely be found in the Americas. Physician Charles Abbott (not a geologist) was one of those who believed he had recovered such evidence from his excavations in Trenton, New Jersey (Abbott 1872a, 1872b). Abbott was certain that his artifactual fossil directors could be used as unambiguous markers for the presence of Paleolithic age man in the Americas. He assumed that similar artifacts found in the Americas were of similar age to those found in Europe. Of his discoveries Abbott (1872a) wrote: "We judge of our 'Indians' by those relics that are now the only trace of their former existence, and finding stone implements as rude as those of Abbeville and Hoxne, we naturally conclude that the fashioners of such 'flints' were so primitive as to be incapable of migration from Asia, and… we cannot think but that there was an autochthonic *[indigenous]* people here in North America, and if an Asiatic people migrated hither, they drove away or absorbed the primitive race that utilized such crude implements." Abbot agreed with John Lubbock (1912[1870]:3) that surely the Indian "savages" of his time could not be "merely the degenerate descendants of more civilized ancestors." There was a pervasive acceptance of a unilinear, evolutionary archaeology dependent upon so-called "diagnostic artifacts" (fossil directors) and modern "fossil cultures" that supposedly still used them in the same fashion as in the past (Meltzer 2006; Trigger 1980, 2004:146, 147). These unprogressive fossilized cultures could be observed from ethnographic data that researchers assumed would explain everything found in the archaeological record (Trigger 1980).

By 1889, intellectuals, geologists, naturalists and ethnologists on both sides of the Atlantic expressed skepticism that there existed an American Paleolithic era (Meltzer 2006). It was a long and bitter dispute, especially with Abbott. There was a spate of presented papers and books that purported to show examples of artifacts from the American Paleolithic (Abbott 1872a, 1872b, 1892, 1893; Lubbock 1912; McGee 1893; Rau 1873; Wright 1896[1889]).

Educated as a geologist, William Henry Holmes spent the best part of his career investigating prehistoric quarries, and became the acknowledged expert in the field (Hough 1933). Transferred from the U.S. Geological Survey to the Bureau of Ethnology in 1889, he quickly examined the so-called Paleolithic sites, described their geomorphology, explained the observed distribution of artifacts, and demonstrated that the "chipped stone implements" were in fact either geofacts, or actually debitage from a flint reduction process carried on at prehistoric chert quarries (Bryan 1950; Holmes 1890, 1894, 1919; Hough 1933; Meltzer 2006; Trigger 2004). Holmes called these implements "quarry blanks" but never actually defines their typology (Holmes 1890).

Holmes determined that mining techniques varied according to a site's geographic and geological settings (Holmes 1919). He documented pits, vertical shafts and horizontal tunneling in different types of outcrops (Holmes 1890, 1894, 1919). He found that prehistoric miners employed stone and antler picks, mauls, sledges, and hammerstones to extract stone, noting that sometimes prehistoric miners even set the hill slope on fire to make it easier to break apart and extract materials embedded in the matrix (Bryan 1950; Ericson 1984; Holmes 1890, 1894, 1919). Though he mostly provided an analysis of what he considered a "study of refuse" at quarries, Holmes did not accomplish what we would consider a modern analysis of lithic debitage, nor did he consider the ages when quarries were utilized (Holmes 1890, 1919; Purdy 1984).

But in fact, what Holmes did that others who came before him did not, was to look at the artifacts found at such sites, and see them as part of a manufacturing *process* (Holmes 1890). Using logic and reason, Holmes discerned that "an artifact might appear 'rude' merely because it was unfinished, not because it was ancient." Comparing "apples-to-apples" he placed purported American paleoliths beside unfinished quarry rejects from American sites, and implied that other researchers had compared "apples-to-oranges" by placing their specimens in relation to bifaces from Europe (Meltzer 2006:24, Figure 2.1). Holmes (1890:11) believed that it was necessary to sort out material in an assemblage which "shows the evidence of design from that which does not." In 1895, John Wesley Powell, definitely influenced by Holmes' work, wrote that:

> In America it has long been conceded by those who believe in " Paleolithic " art as a time or culture distinction that the chipping of implements is not its distinguishing trait, but that the distinction is found in a particular character of chipped implements, i. e., as flakes which we now call chips, as turtle-back forms which we now call rejects, and as rude blades, often broken, which we now call accidents. It has been made clear that these are quarry forms, and that the sites where they are found are to some extent distinguished from village sites; and further, that the quarry forms must not be interpreted as belong-ing to the time when the formations were laid down unless clear geologic evidence demands it, and that only the geologist skilled in the study of overplacement can properly distinguish between primeval gravels and disturbed gravels (Powell 1895:6).

At a joint American-Canadian conference in 1897, none other than Sir John Evans agreed with Holmes' observations and stated for the record that so-called American Paleoliths "correspond in no way with the paleo-lithic artifacts of appreciable geologic age in Europe" and effectively put an end to the American Paleolithic argument (McGee 1897:335; Meltzer 2006). Despite the agreement reached at the conference, volumes such as geologist Newton Winchell's "Paleoliths of Kansas" (which was dedicated to Abbott) continued to be published as late as 1913 (Winchell 1913). In fact, publications such as Barry Fell's *America B.C.* (1976), and others to this day published on the web, still make use of the same flawed logic.

Holmes' Legacy

Alan P. Sullivan (2001:192) writes that "inspired by William H. Holmes, twentieth-century Americanist debitage studies have employed units of analysis, such as object- or stage-of-reduction based taxa or alleged diagnostic attributes that presuppose the origins of individual debitage artifacts." Sullivan calls this the "Holmes's Principle", because it is Holmes, who wrote that in employing those units of analysis, "much is learned about the nature of the work done"—in other words, that a thorough examination of debitage can lead to an understanding of process and behavior (Holmes 1992:134). Holmes not only pioneered the use of data gained from observing debitage directly, he was also the first to study in-situ debitage patterns, and thus to quantitatively establish the difference between a workshop area and raw materials acquisition area (Holmes 1894). Holmes wrote that most of the work of "American tribes" appeared to have been quarrying, an activity he defined as the seeking of materials in "open workings" rather than in deep shafts and tunnels, which he defined as mining (Holmes 1918:155). Holmes saw, in all this activity, an organized process whereby raw materials are quarried, and then manufactured into performs, or "blanks".

Bryan (1950:4) writes that Holmes' narrow focus on the so-called "blank", which he never strictly defines, has "led to insufficient analysis of evidence which might prove that at least some of the quarries were industrial sites at which a variety of articles were made, and that a variety of flint tools were produced to facilitate this manufacture."

Methodology Problems

Ericson (1984) notes that a general lack of technological and methodological theory has caused confusion, and limited the scope of studies of prehistoric mining.

Singer (1984:35) writes that quarries in the United States, and elsewhere, remain understudied because "the areal extent and vast quantity of artifacts can be the most overwhelming aspects of a quarry-workshop site—debitage usually covers thousands of square meters, sometimes square kilometers, and frequencies in the hundreds of thousands or millions are ordinarily present." As a result of these frustrations, researchers mostly describe finished artifacts, tools and other unique items found at quarry sites in order to establish chronologies or lithic reduction techniques (Purdy 1984; Singer 1984; Torrence 1984). Debitage studies can ascertain lithic production rates (and demand) over time (Butzer 1964; Ericson 1984).

A study of mining and quarrying allows for an evaluation of a culture's overall use of technologies (Cobb and Webb 1994:197; Purdy 1984). The lack of attention given to lithic acquisition processes is unfortunate because a complete study of quarrying activities would allow inferences that could describe nearly the entire process of extraction, selection and knapping of materials (Cobb and Webb 1994:197; Shepherd 1980). Whether this lack of attention is due to a limitation of theory or simply a failure to broaden methodology is a matter of debate.

Looked at as a system, the remains of quarrying and mining activities can give insight into how a society was organized, and, in some cases, whether part-time, or full-time specialists coordinated activities (Butzer 1964; Cobb and Webb 1994; Ericson 1984; Shepherd 1980). Unfortunately, though there is evidence of specialized knowledge of minerals, there is little evidence to support extraction, or procurement specialization: "procurement of raw materials appears to have been embedded in the economy as a whole" (Voytek 1997:150).

Hypotheses of exchange behaviors can be developed from studies of debitage found at quarries (cf. Singer and Ericson 1977). In fact, any study of prehistoric economic and social systems should be considered "woefully incomplete" without a study of their lithic procurement mechanisms (Cobb and Webb 1994). Quarry studies might provide essential clues as to whether humans were present in North America in Pre-Clovis times (Purdy 1984). However, quarries need to be studied as a "functional class" of site, in order to be properly interpreted (Torrence 1984). To do this, researchers need to achieve a general understanding of how they compare to all sites with similar economic systems (Torrence 1984:62). Unfortunately there are very few American studies of this sort that are focused on quarries and mines rather than habitation sites for their data. Quarry studies worldwide tend to be unpublished or published in obscure and difficult to obtain journals (Ericson 1984; Shepherd 1980). In addition, quarry studies tend to focus directly on the content of pits and/or the study of debitage exclusively, and thus merely ascertain manufacturing processes rather than inferences of important functions of the site in relation to the overall physical and social environment (Ericson 1984; Purdy 1984; Torrence 1984). Holmes clearly understood that selection and extraction processes depended upon geological settings-- he described complex processes involving clay and fire used to extract flint from a quarry in Ohio, suggesting some kind of division of labor (Bryan 1950:26; Holmes 1918:115, 177). However, specialized procurement remains a controversial topic, and little confirmed evidence exists in the archaeological or ethnological record to support it among Native Americans (Voytek 1997).

There is some evidence that some flint quarries were specialized factory sites, for the manufacture of canoes, for example, or other such tools as was efficacious to do so (Bryan 1950; Ericson 1984; Purdy 1984; Torrence 1984). There may be other such uses of quarries or mines that accurate surveys might yet reveal; however there are few spatial analyses of quarry locations relative to known regional archaeological site surveys. In fact, it has only been in the last twenty years that even major quarry sites, such as Grimes Graves, have been fully mapped and surveyed (Mercer 1981a, 1981b). Indeed, Alibates Flint Quarries National Monument (Alibates Quarries) was not surveyed until 1993 and remains unpublished (Katz and Katz 1993a, 1993b, 2003). There are some three hundred known archaeological sites in the area surrounding Alibates Quarries. A spatial analysis of occupational patterns surrounding the quarries could determine much about the overall social structure of the Antelope Creek people. A spatial analysis of pit locations could detect patterns in the array of quarry pits at Alibates Quarries that could direct future excavation efforts at the park and allow for more inferences regarding the quarrying process and how it was organized.

CHAPTER IV

OVERVIEW OF SPATIAL ANALYSIS THEORY AND RESEARCH DESIGN

Spatial archaeology, or spatial analysis, can be defined as "a set of perspectives on studying ancient societies and cultures, emphasizing position, arrangement, and orientation, and examined from a range of scales: from individual buildings or monuments, caches, burials, to settlements, landscapes and regions" (Ashmore 2002:1173). The mapping of archaeological information is nothing new to archaeology (Carr 1991; Kroll and Price 1991; Shennan 1997). Distribution maps are critical to themes central to archaeology: trade, diffusion and culture inferences are made possible through them (Hodder and Orton 1976). Spatial patterns, co-occurrences of artifact types and distributions, were noted as evidence of chronological range and of social traditions of human groups (Carr 1991; Shennan 1997). Until the mid-twentieth century, culture historians made links between social and spatial data based upon what has been called "intuitive manipulative dexterity learned by rote", mostly from techniques borrowed from those used by art historians and can be categorized as qualitative speculation rather than systematic argument (Ashmore 2002; Shennan 1997:217).

One notable exception was Cyril Fox. His 1923 book, *The Archaeology of the Cambridge Region* was a study he later described (1947) as a regional synthesis that combined artifact distributions with data supplied by geographers and the "environmental sciences". In his book, subtitled as a "topological study," Fox (1923:313) stressed the importance of "geological structure" as it related to the "position and range of Man's settlement". Fox looked for patterns on the landscape that became apparent when multiple lines of data were plotted onto maps of the Cambridge region and interpreted the result as a "distribution pattern of cultural changes" (Fox 1947:20). Though he later admitted, that some of the conclusions he made as a result of his study were sometimes inadequate, he claimed that this was mostly due to "progress in science" since its writing, and not with any fault that might be found in his forward-thinking interdisciplinary methodology (Fox 1947). However, while Fox was concerned with recording and analyzing the spatial dimensions of archaeological materials, his work cannot be said to have been quantitative in nature (Wheatley and Gillings 2002).

Perhaps the first mention of the use of quantitative statistical devices for use in archaeological inference was by A. L. Kroeber (1940). His main means of computation was a simple *chi* square which was used to compare correlates to discover "a classification of the relative degree of likeness, which takes on meaning from the relation to other such generalized expressions of likeness" (Kroeber 1940:30). He called this technique "the coefficient method". Kroeber asserted that misrepresentative results are returned when there are data that differ greatly from others in the set, in other words when two or more distributions of categorical data are dissimilar. He also commented on the limitations of analyzing too small of a sample and submitted that "archaeologists do not yet collect or describe quite uniformly" (Kroeber 1940:37). Kroeber (1940:29) wrote that statistical comparison was a useful inductive means of analysis that yields a classification, but that interpretation "in terms of cause or sequence is a subsequent and non-statistical matter". By the late 1940s, Walter Taylor (1973[1948]) was arguing for a "conjunctive approach" to archaeology in order to make social inferences that included behavioral and functionalist analyses of archaeological materials, as opposed to the time-space descriptions of culture history. Taylor believed archaeologists should seek out "the 'affinities' within the manifestation under investigation" (Taylor 1973[1948]:93).

In the late 1940s and 1950s, there was a resurgent interest in evolution and a rise in Marxist materialist theoretical perspectives. Influenced by the work of Lewis Morgan (1877) and Marxist archaeologist V. Gordon Childe (1965[1936]), researchers devised evolution-based, adaptationist approaches to explaining culture change, and lent more weight to environmental and spatial data.

Leslie White (1949) was a proponent of a universal or general cultural evolution. White, along with Childe, related Morgan's cultural stages to the culture of mankind as a whole, although White focused in on the context of energy production and control (Childe 1965[1936]; Morgan 1877; White 1943). Julian Steward (1976[1955]:16) noted that both Childe and White excluded as *irrelevant* "the empirical research" that had delineated distinctive cultural traditions and local variations "which have developed as the result of special historical trends and of cultural ecological adaptations to special environments". White (1949:338-339) wrote that "(t)he functioning of any culture will of course be conditioned by local environmental conditions. But in a consideration of culture as a whole, we may average all environments together to form a constant factor which may be excluded from our formulations of cultural development". Childe (1951) posited that all cultures have lived in a multitude of different historical and natural environments and that research focused on those different environments inhibited what he believed to be the main goal of archaeology, that of establishing "general stages in the evolution of all societies". He further commented that because of the descriptive nature of those enquiries, "we abstract… the peculiarities due to the differences of habitat" (Childe 1951:35) – differences Childe clearly did not believe important, and that Steward (1976[1955]:17) believed were rationales for the "involved effort to enlist diffusion in order to effect divergent evolution… based on Old World data".

Steward saw natural space as having a *direct* effect upon cultures: cultures evolved multi-lineally and in ways uniquely suited to their particular natural environments (Steward 1976a [1955]:120). He spent a considerable amount of time studying the Great Basin Shoshone Indians and posited that in only their particular environment, with all of its unique combination of material and faunal factors, could family units such as seen with the Shoshone have evolved. Steward took ethnographic information he collected from living Shoshone and illustrated how environmental conditions forced the normally independent family units to work collectively at certain times of the year (Steward 1976a). He noted that the Shoshone had regular "seasonal rounds" wherein they could work cooperatively and also socialize, thereby creating cultural traditions—however, these few "interfamilial pursuits did not seem to give cohesion to extended families… or other higher levels of sociocultural integration as in the Southwest" (Steward 1976a:119). He inferred that while the Shoshone had a material and technological culture similar to the cultures of the Southwest, their economic, political, social, religious and hostility patterns owe themselves entirely to cultural ecological processes (Steward 1976a:118). Steward proposed that explanation of the existence of patrilineal bands rested on identifying what he called "exploitative patterns" in the natural environment (Steward 1976b). Steward summarized his career and what he thought should be the major focus of archaeology when he wrote (1976[1955]:21) that he had "endeavored in various studies to demonstrate how cultural-ecological adaptations—the adaptive processes through which a historically derived culture is modified in a particular environment—are among the important creative processes in cultural change". Steward's ideas echoed Fox's 1923 position (albeit without emphasis on geological data) and concluded that if researchers were interested in seeking out the social dynamics of hunter-gatherers they should consider that a regional, focused spatial/geographical analysis of the ecological patterning of a landscape could be more informative than an analysis of only recovered artifacts.

Albert Spaulding (1960: 437-439) noted that the dimensions of archaeology consisted of form, temporal location and spatial location, and that they were the basis for characterizing and analyzing artifacts and archaeological assemblages. He further noted that the aim of archaeologists was to "describe clearly the fundamental operations of archaeology based on its empirical data" (Spauding 1960:437). Spaulding (1960:437), however, saw behavioral or social interpretation of these data as "evidence of weak-mindedness" -- since statistical laws can only provide estimates with confidence limits or probabilities of occurrence, they are not exact values (Read and Leblanc 1978).

In his groundbreaking essay, "Archaeology as Anthropology", Binford (1962) contradicted Spaulding, asserting instead that a study of archaeological remains can indeed allow for inferences about the social as well as technological and ideological life of ancient cultures. Binford incorporated the work of Taylor, White, Steward and

Spaulding with an explicit concern for scientific methods and field research designs (Redman 1991). Binford (1977) wrote that human behavior always takes place within a "spatial theater" and that this behavior is conditioned by relationships between all of the possible uses of a particular space and any labor or social pressures that operate among people who are doing organized activities there. Binford (1977:9) further noted that "(i)f we could isolate even some of the constraints that are operative, within a dynamic system, we might well be able to analyze at least some aspects of past behavioral systems in structural terms rather than the more commonly emphasized formal or content categories of tool frequencies, types, and so on".

According to Binford (1977:6), patterns must first be discovered within a dataset, then analyzed, and logically related to formation processes—only then can it be related to "some identity" (Carr 1991:222), what Binford (1968:27) referred to as "developing laws of cultural dynamics". It is the comparison of systems, and not traits that provides data for understanding trends and for the discovery of regularities—only after these regularities are understood could one make probabilistic predictions (Martin 1972). The initial goal is to identify patterns and not to interpret them, instead to discover the pattern of groupings within a data set "with as few assumptions as possible about the nature of the grouping" (Shennan 1997:220). Christopher Carr (1991:223) uses, as an example, the spatial patterns of artifacts around a prehistoric hearth, "suggesting their having been dropped, might be used to identify the hearth is a men's outside hearth rather than an interior one". This contrasts with "interpretation", something that explains a pattern "among inferred facts or data by subsuming it under some theoretical framework"—using the example noted above, those data could be interpreted using social and economic theory concerning division of labor (Carr 1991:223). Carr (1991) further notes that while the process of identification leads to reconstruction of conditions in the past, the process of interpretation "often involves relating variables to each other." Binford (1980) illustrated this when he asserted that prehistoric spatial patterning can be explained by direct analogy with similar patterns observed in contemporary hunter-gatherer groups. A broader approach can be seen in the work of Kent Flannery (1976) who utilized spatial analysis in his studies of Mesoamerican villages. Flannery illustrated how spatial patterning of archaeological remains could be used to reconstruct household organization. Flannery's work gave rise to a spate of "settlement studies" that referenced the changing relationships between "people and their natural environment, and the influence of demographic pressures on social organization" (Seibert 2006:xv). These studies were limited in their theoretical scope, and according to Jeffrey Siebert (2006), can be seen as "exemplifying the marriage between cultural ecology and processualism that typified much of the work of the 1970s in the Americas". Redman (1991:302) characterized Flannery's work as a "dialogue with the data", and noted further that "Flannery gives these dialogues substance and importance by his personal insight, not by the rigorous use of evidence in a process of scientific validation". Ashmore (2002) wrote that while Flannery's studies proposed spatial correlates for the designated social units (villages and households in this example), and while these spatial relations alone do not confirm the "materialization" of social units, nonetheless, Flannery linked social and spatial data more explicitly than anyone had done previously.

In the late 1960s and early 1970s, some archaeologists became influenced by the work of R. J. Chorley, who sought statistical methods for interpreting landscapes. The more information contained in a given map, what Chorley and Haggett(1965) called "signal", the more ambiguity and uncertainty there was likely to be in its interpretation—what Chorley and Haggett referred to as "noise" (Wheatley and Gilley 2002:6). The resultant subjective interpretation of distribution maps was seen as a potentially "dangerous" source of disinformation; there was a need for more quantitative methods of correlation for locational analysis (Clarke 1977). Chorley and Haggett (1965:47-48) noted that the way to treat areal, or mapped regional information, was to use statistical analysis, something which would

> "disentangle the smooth, broader regional patterns of variation from the non-systematic, local and chance variations, and then to ascribe mechanisms or causes to the different components… thus, the regional effect is commonly viewed as a smooth, regular distribution of effects, termed a *trend surface* or *trend component* which are too deep, too broad, and too great in relief to admit of the purely local explanation which is reserved for the *residuals* or *deviations".*

Trend surface mapping was seen as a means of inferring dynamics or processes--"an attempt to build up some generalized picture of areal variability in order to test some *process-response model*" to explain distributions (Chorley and Haggett 1965:48). As an analysis tool in archaeology, "it is capable of detecting a geographic patterning of spatially-distributed data, and pointing up areas of the spatial distribution which deviate from this pattern" (Roper 1976:182). Donna Roper (1976) used this technique to confirm the postulated south-to-north trend of movement by bearers of the Central Plains cultural tradition. She mapped reported radiocarbon dates by superimposing linear trend surface contours that represent those dates onto a map of the archaeological sites from which the tested samples were recovered. This map visually illustrated that the reported south-to-north trend was largely supported by the chronological evidence (Roper 1976:187).

Another method for locational spatial analysis was termed "site catchment analysis" by C. Vita-Finzi and E. S. Higgs (1970:5), who defined it as "the study of the relationships between technology and those natural resources lying within economic range of individual sites". Similar to "central place theory" which concerns distances between settlements and markets, in site catchment analysis, it is assumed that the farther one moves away from the source of a desired resource, more energy is required to procure the resource, and therefore the intensity of exploitation decreases, eventually reaching the point of unprofitability (Roper 1979:120-121). Roper (1979:122) outlines site catchment analysis as that which "delimits a territory or set of concentric territories surrounding a site and assesses the resource potential contained within that area… the territory assessed is that postulated to be the area from which the greatest quantity of resources was derived". Because there was a "hierarchy of the importance of resources" (for example, water was more important than other resources), "a differentiation of use, or zonation, of the territory surrounding a settlement, occurred" (Roper 1979:121). Higgs et al. (1967) used this technique to analyze resources used by Paleolithic sites in Epirus, Greece, and was able to discern variation in seasonal and spatial distribution of resources. However, even though their conclusions were judged valid, their assessment of resources was defined by arbitrary 10 km rings used to denote zones, and this distance was not quantified (Roper 1979:122). Higgs and Vita-Finzi (1972) later decried the use of static or arbitrary boundaries and noted that boundary radii used to delimit resource areas should be determined from careful study of local terrain (to look for natural boundaries, for example) and determination of the time it would take for a site's occupants to traverse those distances. Higgs and Vita-Finzi (1972) posited that prehistoric economies could be classified as to whether they were mobile, sedentary, or mobile-cum-sedentary. Site catchment analysis is valid, they wrote, because "the concept of economic territoriality allows us to delimit the habitually exploited area around a site from which any of *[these]* types of economy *[were]* practiced (Higgs and Vita-Finzi 1972:36).

Also disputing the efficacy of analysis by inspection, or impressionistic interpretation, Robert Whallon (1973) denoted a three-step method to judge the significance of spatial aggregation in a distribution, and of the similarity between distributions. Before statistics can be applied to a distribution, it must first be determined if the distribution of items of each class is random, or shows a tendency toward spatial aggregation or concentration on a scale smaller than the area under analysis. Secondly, the items that do show a tendency toward concentration are reorganized such that similarities/correlations that reflect these concentrations can be calculated among the classes. Lastly, similarities and correlations in spatial distribution are calculated and displayed in some form, either in matrix, or in a tree form defined by cluster analysis, "so that groups of artifacts and items which are similarly distributed over the area considered are defined, along with the relationships among these groups or clusters" (Whallon 1973:266-267). Whallon (1972) pioneered the use of dimensional analysis of variance and nearest neighbor analysis for distribution analysis of lithic materials on occupation floors. Whallon (1984) argued that statistical methods have an objective validity, but that researchers need to be sure that the methods they use are appropriate to the questions they seek to answer. He noted that there were critics of his and others' analytical methodologies, especially those coming from archaeologists whose interest (at that time period) was ethnoarchaeology (Whallon 1984).

Certainly, through the 1970s, there were plenty of critics of processualist approaches to archaeology, especially with regard to space-time issues. Arnold (2003) summarized this criticism, commenting that processualists promoted the notion that the archaeological record was a laboratory in which scientific research was carried out (e.g. Plog 1974; Watson et al. 1971). Perhaps the staunchest critic of Binford's (1964:425) basic premise that "the loss, breakage, and abandonment of implements and facilities at different locations, where groups of variable structure performed different tasks, leaves a 'fossil' record of the actual operation of an extinct society", was Michael Schiffer. Schiffer (1995[1972]) noted that Binford did not take into account all aspects of the *formation process* of archaeological sites. He argued that though archaeologists take into account the concept, that assumptions they make about them are rarely explicit and deal only with chronological relationships (Schiffer (1995[1972]:25). Schiffer (1995[1972]:33) proposed that researchers desiring to do archaeological testing need first to define detailed "high-probability statements" about how activities at archaeological sites were structured, hypotheses about the composition of task groups, their means of recruitment, how the groups fit into the overall social structure, and especially, how the organizations' structure changed, or adjusted to change. This "activity structure", Schiffer (1995[1972]:33) wrote, would then be linked to the archaeological context data by site formation processes, both cultural (what Schiffer calls C-transforms) and non-cultural/natural (N-transforms). In other words, until the non-cultural processes that affect deposition at sites are examined, the archaeological record will be "a distorted reflection of a past behavioral system" (Schiffer 1995[1972]. David Clarke agreed, and noted in a 1973 essay that archaeologists only possessed a small sample of what they desire to study, and that archaeology would remain "an irresponsible art form" without a systemized (analytical) body of theory that related remains to human behavior (Clarke 1979[1973]:83-103). Clarke (1978[1968] had already written about systems theory and how it was necessary for archaeological data needed to be scrutinized using its more analytical concepts. It must be noted that Schiffer's schema for articulating site formation processes "did not embrace Clarke's analytical level" (Trigger 2004:359). Trigger (2004:370) notes that Clarke "viewed archaeology more broadly as the potential nucleus of a general science of material culture, past and present that would complement social and cognitive anthropology". Clarke (1977:9) defined spatial archaeology as a study of the scale levels of the "spatial consequences of hominid activity patterns within and between features and structures and their articulation between sites". Clarke (1977:20) was skeptical that archaeologists could "determine all the factors which governed individual decisions and dispositions, especially prehistoric ones" from spatial data. He was more concerned, as was Binford, with space as it related to specialized activities as opposed to social inferences, and with creating a more scientific discipline of archaeology (Ashmore 2002; Trigger 2004).

Binford et al. (1970) mounted an extensive excavation at the Hatchery West site in Illinois and pioneered methods of field excavation that included extensive spatial analysis based upon the mapping of recovered artifacts and archaeological features. One such map showed the distribution of sherds from the Late Woodland Period over the entire area encompassing the targeted research site as well as known data from nearby related archaeological sites (Binford et al. 1970:4). The sherd distribution is plotted in zonal fashion, along with details of terrain, such as topography and plow zones. Areas are shown at different scales, giving the overall picture of not just the focus site, but a regional layout of archaeological zones (Binford et al. 1970:5). By delineating areas of highest concentrations of related materials and resources, Binford and his colleagues were able to identify particular activities and the specific means by which they were organized. To do this at highest resolution, they superimposed sample areas upon surface distributions, "localizing" distributions in order that they could be plotted graphically and analyzed statistically. The resultant data indicated which areas were to be characterized as non-random clusters (of sampled materials), or as Binford et al. (1970) denoted them: activity areas.

Ian Hodder (1972) investigated the spatial patterning of cantonal capitals and lesser walled towns by constructing Thiesson polygons around them and then analyzing the distribution of settlement. In his conclusions, Hodder (1972:227) noted that a problem with interpreting an observed spatial pattern is the difficulty in choosing between alternative theories that are equally applicable to the same spatial pattern: known as the "equifinality problem". The excavation, plotting and overlay of the distribution of artifacts recovered at nearby sites, he claimed, would illuminate the "functional inter-relationship of settlements" (Hodder 1972:228). However, the interpretation of these plotted data requires an archaeologist to consult materials outside of their usual interests, i.e., to investigate the links that "connect prehistory to modern geography" and ethnological studies—in effect, to place heavy emphasis on *contextual data*; to define what attributes of data are most relevant and *interconnected* (Hodder 1972:228). Hodder and Orton (1976) further delineated methods by which contextual data can be evaluated into unambiguous representations, for example, through careful analysis of the relationship of artifact distributions a researcher can define spatial uniformity using nearest neighbor analysis, then relate that observed pattern as the result of social behaviors. They promoted the use of random or stochastic processes for the modeling of spatial patterns, noting that "

> (w)e expect non-random spatial patterns because we know that individual behavior is not random but is constrained and determined by, for example, kinship factors in the exchange of goods and physical factors in the location of sites. However, it will be found that non-random behavior is often not apparent in the spatial patterns. Many of the observed archaeological patterns have a form which is similar to patterns produced by a random process. If the form of the pattern is similar to the end result of a random process… aggregate human behavior is often best simulated by random process, or by very simple models incorporating a strong random element (Hodder and Orton 1976:9).

Hodder and Orton (1976:9) assert that it is only when all constraints of a decision are understood that behavior can be considered rational, "and this is the level at which social anthropologists are able to work in studying human interaction. Using polygons and other statistical methods for pattern discernment, Hodder and Orton (1976) articulated gravity (flow of materials/interaction between centers) and central place models for determining what they claimed would be "true" archaeological patterns of human settlement and economic and technological systems.

Butzer (1980:421) declared that "archaeology is a complex social science in its own right" He (1980:421) decried Willey and Phillips (1958) statement that "archaeology is anthropology or it is nothing", and wrote that "archaeology has been [not only dependent upon social, ecological and evolutionary anthropology, but also] equally dependent on stimuli and models grounded in geology, biology and geography at sometime during its development". He (1980) defined an environmental-focused contextual archaeology. In Butzer's opinion, "environment" was more than "a body of static and descriptive background" but instead contained the basic contexts of archaeology: the "environment" is the sum of all of the elements an archaeologist might study (Butzer 1980:418). He provided an archaeology-centered definition of "context" as implying "a four-dimensional, spatial-temporal matrix that comprises both a cultural and non-cultural environment and that can apply to a single artifact or to a constellation of sites" (Butzer 1980:418). According to Butzer (1980), there are five central themes that have direct anthropological and archaeological application: space, scale, complexity, interaction and stability. Butzer (1980:418) claimed that each of these "properties" were "measurable and therefore replicable, and so amenable to scientific study".

Research in the mid and late 1970s saw increasing interest in overtly social approaches to spatial questions in archaeology—they began to examine "less 'tangible' aspects of human culture, such as ideology, and began to critically analyze power relations and social structures in past societies" (Seibert 2006:xv). New analysis techniques were introduced that focused functional and processual approaches to spatial archaeology more on "the social and cultural implications of spatial relations in past cultures" (Seibert 2006:xvi). This new, post-processional archaeology "gave the social, cognitive and cultural aspects of spatial analysis centre stage" (Seibert 2006:xvi).

However loud the call was for a scientific archaeology, in the opinion of many researchers (cf. Clarke 1979[1973]; Hodder 1972, 1982, 1988), processual archaeology was bogged down in analyses of long-term processes that seemed to do nothing but obfuscate the interpretation of social organization and hinder the development of theory. In a heated correspondence between Hodder, Binford and Nancy M. Stone, Hodder (Hodder et al 1988:373,374) accused Binford of diverging from anthropological concerns:

> On the anthropological side, there is human agency, structure and event, culture and economy, the reactions to deconstruction and critical perspectives... On Binford's side, there is bone taphonomy, traces of use wear on flint, and hunter-gatherer foraging strategies... I do not understand why Binford thinks that the material world was not patterned meaningfully in the past and that traces of these past patterns do not survive in the archaeological record.

Hodder also noted that Clarke (1968:102) saw the "social subsystem" as a subset of the "sociocultural system", all of which was characterized as "the hierarchical network of inferred personal relationships, including kinship and rank status". Social systems and social relations were seen as "subordinate to the environment and to economic and technological subsystems" (Hodder 2003:70). Read and Leblanc (1978:308) commented that the "new archaeologists" (processualists) "unduly emphasized the testing of hypotheses and the form of explanation at the expense of the content of hypotheses and the construction of explanatory arguments" and that the "failure of many new archaeologists to consider adequately the role of theory in scientific explanation had led to "sterile proclamations about the nature of scientific methodology that fail to come to grips with the difficult epistemological issues facing the archaeologist… about what constitutes adequate theory … and the role of archaeological data in that theory."

Systems theories had certainly proved their value to researchers, but their application had created the notion of cultures as unchanging, or could not explain why they changed. Hodder (1982:5, 13) noted that "adequate explanation of social systems and social change must involve the individuals' assessment and aims", and further, that the processualist goal of cross-cultural explanation for human events was inappropriate as it denies the uniqueness of individual cultures and historical circumstances."

James Deetz and Richard Bushman (1974:21) conceived of an "explanatory model which uses material culture to indicate and reflect the non-material dimensions of culture" and noted that "in most instances at the somewhat more simple end of the complexity scale (in terms of socioeconomics) this tended to become buried in more imperative aspects of culture"--- "one could suggest that the cognitive dimension of material culture assemblages may tend to surface to a greater degree as one moves up the scale of complexity". In his study of Plimoth Colony area in New England, Deetz and Bushman (1974:23) noted that the use of certain drinking containers were for decoration only and fit in with Binford's notion of an artifact as having a socio-technical function, but he also comments on "the Georgian mind" and assessed the layout of the Georgian farm by referring to its bilateral symmetry, and noted that the special structure fit into "the Georgian-derived cognitive system" which "stems from the concept of an ordered universe". Deetz (1988:363) wrote that archaeologists should use the material record as a jumping-off point, and that they "should seek explanations for their data in terms of the known history of the region and time represented by their material".

Susan Kent (1987) was interested in the spatial analysis of activity areas and advocated complete excavations of sites. She wrote (1987:11) that anyone interested in "the general use of space at a site and how this use changes over time" does not want a representative sample of archaeological remains at a site "since the distribution of activity areas and refuse loci are probably not random or even scattered through a site". Kent complained (1987:11) that "we *[archaeologists]* use sampling strategies and sizes based on our assumptions of how sites in general, and our site in particular, are internally organized, rarely questioning these implicit assumptions." Using data from the excavation of a year-round Navajo camp, Kent (1987:12) showed "that for reasons we cannot fully explain, the occurrence of outdoor activity loci at variable distances from major architecture at a site is not necessarily neatly patterned". In addition, she provided ethnographic studies from other cultures, and noted how consistency in spatial variables shifted when mobile groups were examined (Kent 1987:18). In Kent's view, more cross-cultural ethnoarchaeological studies are needed in order to ascertain the variables affecting spatial patterning in relationship to other features and dwellings at sites of both sedentary and mobile cultures.

Kent (1991) also observed that many archaeologists studying hunter-gatherer groups emphasize human ecology from a theoretical orientation that focuses too much on "density relationships," and frequently find themselves when comparing cultures from radically different environments—of course, they frequently note variation. She writes (1991:34) that "differences in the environment may appear to be responsible for the variation… *[however,]* emphasis on related ecological variables alone—such as environment, seasons, and predators—makes it impossible to determine whether the variation would still occur if the groups were in the same setting; that is, that the variation is the result of other factors." Kent (1987:46) wrote that only "by identifying and understanding all of the related variables, the intimate relationship among culture, behavior, and cultural material, and the patterning that the interrelationship produces" can we "formulate reliable predictive models that will greatly enhance our understanding of the archaeological record, and the various cultural, behavioral and natural processes that created it."

Michael Shanks and Christopher Tilley (1988) noted that part of the problem in interpreting spatial variation, was that archaeology was only interested in "units larger than the individual". Even as far back as the early 1960s, Edward T. Hall (1963) questioned why researchers still had no methods "for noting and describing *[the human}* experience of space" or spatial etiquette across cultural boundaries. The relationship between spatial organization and social behavior is important because"(s)pace is not passive; it is socially constituted and constituting, materialized in architecture, and also, if less tangible, in customs of social interaction" (Ashmore 2002).

Binford's (2002) response to this kind of thinking was anything but complementary. He did not agree with "agency" concepts, or that the proper "unit" of research should be the individual, and noted that

> The fact is that archaeologist's units are demonstrated forms of patterning derived from the analytical study of the archaeological record. In most cases it takes considerable behavioral repetition to produce a recognizable pattern in

> archaeological remains. Such a pattern is, of necessity, the result of *many* individuals behaving similarly in different locations or venues. The different repetitive patterns must be convincingly integrated into a model of the organizational characteristics of past social forms… such issues as the 'proper' unit for discussing causation, or the confusion of a referral argument with an explanation, have deflected productive research… (Binford 2002:234).

By the beginning of the 1990s, Geographic Information Systems (GIS) technology began to be used by archaeologists responsible for the inventorying of regional archaeological records (Wheatley and Gillings, 2002). GIS are computer systems "whose main purpose is to store, manipulate, analyze and present information about geographic space" (Wheatley and Gillings 2002:9). GIS offered a means of coordinating the vast amount of information already stored on maps at universities and in state archaeological archives. By the late 1990s, it was difficult to find a regional survey projects that did not make use of GIS, especially in the United States.

It is important to note that GIS does not represent a theoretical approach in and of itself (Seibert 2006). GIS is not in itself a "school of thought" and so does not attempt to explain social and cultural phenomena. Therefore, debate about the uses of GIS analyses presently centers on how it affects archaeological theory. Wheatley and Giddings (2002:20) note that "unthinking use of GIS can lead unwittingly to interpretations of culture that overemphasize the impact of environmental factors as the prime mover for cultural activity". Others, such as Adam Smith (2003), see archaeologists using GIS to subvert notions of space under ideas of social evolution, tying the technology to only temporal and chronological concerns. In addition, GIS analyses are often done with poorly collected data, and errors are compounded from ignorance of the capacities and limitations of the technology. Regardless of these debates, GIS use in archaeology continues to broaden and increase in popularity.

Post-survey data distribution models for the Alibates Quarries pits

The purpose of this thesis is to ascertain whether there is two dimensional spatial patterning of quarry pits at the Alibates Quarries. Spatial patterns identified among the quarry pits located at the quarries should reflect work areas by corporate, or other organized groups and if they controlled the enterprise. By studying the remains of activities and their proveniences (artifacts, debitage, middens, etc.) the logistics of those activities may be inferred.

It is important to remember that what are presented here are models. Peter Haggett (1965:2) noted that "order and chaos are not part of nature but part of the human mind… order depends not on the geometry of the object we see but on the organizational framework into which we place it". LeRoy Johnson, Jr. (1972:309) wrote that "when an archaeologist engages in scale analysis, cluster analysis, or other similar study, in effect he determines some kind of agreement or fit between his data and an imaginary, structured system of data relations".

Critical to a model is the paradigm by which it operates under, relevant in this case, is what Clarke (1972:7) called the "Geographical Paradigm": "the study of sites as patterned systems of features and structures within systems of sites territorially distributed over landscapes in a mutually adjusted way."

Three models of pit patterning will be used to analyze survey results. Pit systems can be seen as nodal regions. Nodal regions begin with some "movement" in and out of a region, resulting in networks of movements and locations, or nodes (Haggett 1965:18). These nodes are spaced and sized within a system that, ideally, maximizes expenditure of energy needed to complete whatever process the nodal system engenders, bounded by whatever social or cultural rules that might be in effect.

In the *Overseer Model* there is a systematically organized distribution of pits with little overlapping and little clustering: this arrangement would be considered an ideal, non-random dispersal, as opposed to a "condensed" non-random cluster (Figure 4-1). This model would indicate organizational control over mining operations, in other words, some sort of overseer who would systematically manage the use of space at the quarry in order to maximize output. The implication here is that there is some sort of overarching central authority for which laborers are working, and that the efforts of their labor are pooled. In this scenario, all pits are likely quarries, as there is no immediate room for other features which would indicate work areas wherein reduction of raw materials could take place. In this model, other locations must be searched for work areas; those work areas would also likely be very efficiently spatially parceled. If pits are spaced apart, in this model, it would be reasonable to assume that that spacing would be consistent between each and every pit.

Figure 4-1. Systematically organized pits of the *Overseer Model.*

In order to fit the *Competing Groups Model* pits will be arranged into clusters or dispersal groups with clear divisions between pit groups. Overlapping of pits is possible within clusters (Figure 4-2). This arrangement of pits would indicate that competing kin-based, corporate, or some other type of specialist group, had oversight of their own sectors of the quarry—overlapping of pits would indicate a maximizing effort to mine every bit of lithic material within their sector. There might be some observed linearity because it is plausible that the same efficiency observed in the overseer model could be seen initially in the competing groups model--- a key indicator of the difference between these models will be a noticeable gap between statistically non-random clusters. It is imperative that statistical testing be done to ensure clusters are not the product of random dispersal.

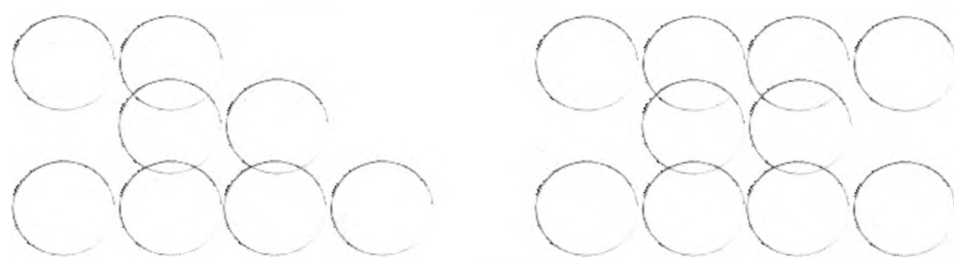


Figure 4-2. ***Competing Groups Model*** **showing two sectors, or clusters.**

In the *Random Model* there is no apparent pattern to pits—observations of this model include random overlapping of pits and little statistical evidence of clusters (Figure 4-3). Under this model individuals would act alone, or in informal groups, mining chert for both their own trading inventory and for their own personal use. Since there is no overseer, or organized group involved in the process of laying out pits, individuals were free to impinge upon other pits, and to begin pits anywhere they pleased, according to their own judgments. This model implies that miners are part of an egalitarian-type society; it is the pattern that might be expected from use of the quarry by hunter-gatherers, or several unrelated mobile groups over time. It is also plausible that a pit array could appear random, and even statistically test as random-dispersed, if the "governing" system of mining were to shift over time, wherein, organized labor was displaced by a more egalitarian system, for example. The resulting random placement of pits superimposed over an *overseer model* of pits, would be difficult to observe without field work or excavation. Inferences regarding the work of individuals are always difficult, if not impossible to quantify in large scenarios. These are just some of the equifinality scenarios where statistical testing alone would not illustrate a true picture of activities at the quarries.

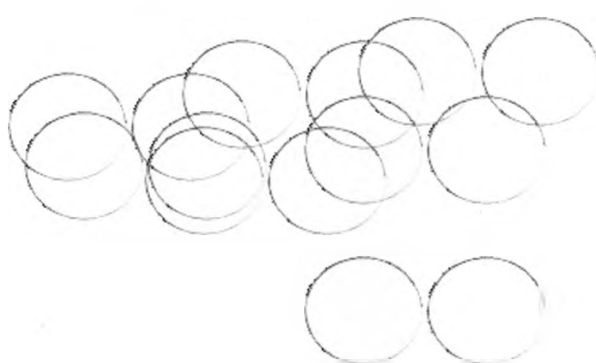


Figure 4-3. *Random Model* quarry pit patterning.

Of course, interpreting these patterns is not the main objective of this thesis; pattern identification is its stated purpose. However, without models to compare research results against, there is no way to proceed from simple statistical facts about the clustering of pits. In fact these models act as visualizing and organizing devices which might aid in the construction and development of theories surrounding the activities at Alibates quarries (Clarke 1972:2).

Additionally, an assumption was made that the closer pits were to each other, the more they might be related. Pits were therefore examined by seeing which surface area classes of pits might show such patterns: is it possible that two or more classes might show patterned "zones of influences" that would indicate some kind of relationship? Could pits of different surface area showing these patterns be an indication of the means by which mined materials were processed? Are the pits spatially patterned according to any of the articulated models?

CHAPTER V

METHODOLOGY

The results of this thesis work are based upon survey data collected by Susana R. and Paul Katz and crew from December, 1998 through April 1999 during an intensive archaeological survey of the Palo Duro fire area. They surveyed the Alibates Flint Quarries National Monument (Alibates Quarry) and adjacent portions of Lake Meredith National Recreation Area in Potter and Moore Counties, Texas in five 1000 meter blocks (Katz and Katz, 2003). Katz and Katz (2003) produced a paper reporting the results of their projects, but, a detailed report has not been published.

Paul Katz (personal communication, 2009) described the methodology of the Katz and Katz field survey and data collection as occurring in two phases: "Two complete sweeps of Site 100 *[Alibates Flint Quarries National Monument, 41PT1]* were made. The first located the pits and recorded a suite of attributes. These included dimensions, estimated pit depth, and debris ring height; morphological characteristics; proximity to or intersection with adjacent features; and associated surface artifacts. Each feature was then visited a second time, when it was mapped and photographed."

Pit morphologies were described subjectively, chosen from a set that included linear, circle, ellipse, crescent, polygon and indeterminate shapes. Data were entered into database forms held on Palm Pilots (model IIIs). "Each pit was assigned a consecutive integer identification number, beginning with #001 and ending with #734. The number was placed on a pin flag and on a piece of flagging fastened to a metal spike. Both flag and spike were positioned in the *[perceived]* center of the pit so that it could be located again during the mapping phase (Katz and Katz 2003:14). However, these pin flags were not left in place after the mapping phase was completed. It should also be noted that five of the pit locations recorded by the Katz team were discarded because when mapped, they fell far outside of a map of Alibates Quarries— the resultant 729 valid pit locations were then used for analysis.

Katz and Katz (2003:14) described the second phase mapping work as involving the use of a Sokia EDM (Electronic Distance Measuring instrument, model not cited). "Kathy Bartsch, the data analyst during the survey, recorded the distance and direction of the pits from a total data station we established" (Katz and Katz 2003:14). EDM is actually but one function of a total data station (TDS). The TDS is an electronic transit that allows for distances to be measured from the instrument to any particular point in the field. Due to the hilly terrain, nine data stations (bench marks, or mapping datum points) were established which encompassed the survey area (Figure 5-1).

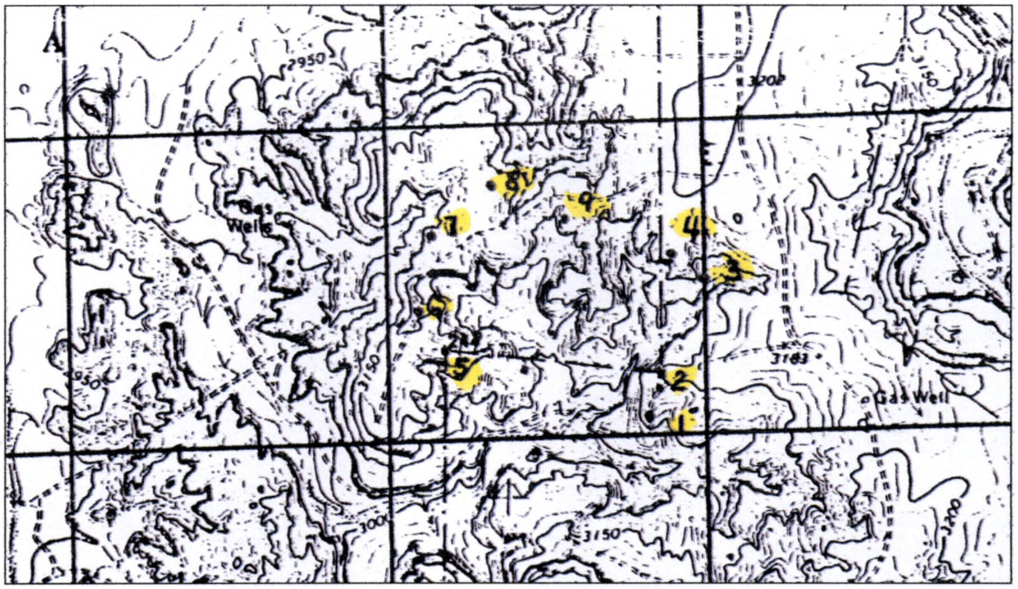


Figure 5-1. Map showing nine Katz and Katz (1999b) assigned data stations.

According to the Katz and Katz field book notes (1999a), at least two of the data stations were brass caps marking boundaries for the park (Stations 2 and 5). One crew member manned the EDM "while a second crew member held the target in the center of each pit and then retrieved the pin flag [*left during the first phase of the survey]* after the distance and direction from the data station was measured by the EDM" (Katz and Katz 2003:14).

Unfortunately, UTM coordinates for the data stations were determined by the use of early-model handheld GPS receivers, in this case, Garmin II GPS receivers. This complicated the calculation of errors. Prior to May 2, 2000, handheld GPS systems were subject to SA, "selective availability", "an artificial falsification of time in the L1 signal transmitted by the satellite providing the GPS reading" (kowoma.de 2010). Selective availability (SA) caused errors of up to 50 meters over only a few minutes. Kowoma.de, a web site created by GPS consultants located in Germany, note that in an experiment looking at points collected within a 50 meter radius both before and after the use of SA, that 95% of the SA points were located within a radius of 45 meters, while the post-SA readings placed the same 95% of points within a radius of only 6.3 meters (kowoma.de 2010). It is fortunate that only the data station locations were located with GPS, and that the pit locations were determined with the EDM from each of the nine mapping points—in this way, two dimensional pattern arrays were not compromised.

The Katz and Katz field crew (Katz and Katz 1999a) notes the use of backsighting: However, multiple backsights were used for each data station. A backsight reading is a bearing based on a point of known elevation—a surveyor will take a backsight reading on a level rod held in its unchanged position (and known elevation) while the instrument (usually a TDS) is moved to another position: backsights lock the instrument into a designated mapping coordinate system (Pyburn 2003). Taking a backsight is critical to maintaining accurate elevation and angular information as the survey instrument is moved from place-to-place. But the locations of all of the data stations/datum points were recorded with GPS, and since each station had a different backsight, it appears that all of the stations were tied into their own coordinate grid and n ot integrated into a single coordinate grid system. Orientations for each area, within each data set are accurate, but not in relation to each other. Therefore to be sure of a correct orientation between station groups, a series of points needs to be relocated from each mapping station with an accurate (sub-meter, or better) GPS; those points can then be used to correct offsets and angular differences..

In addition, the Katz and Katz crew members took bearing readings based on magnetic rather than true north, and introduced even more errors that would need correction before UTM coordinates could be calculated and features plotted and mapped.

For this thesis, magnetic declination errors noted by the original crew members were compared to those computed by an "estimated Value of Magnetic Declination" calculator located on the National Geophysical Data Center (NGDC) web site (NGDC 2008). When there was a difference between the crew's computed error and the NGDC computation, the NGDC computation was assumed as more correct and that computation used in place of the original. Since the GPS, with its errors, was used for location of all of the data stations/datum points, the TDS would not be able to precisely locate any of the quarry pits—they would all be inaccurate by some unknown numbers of degrees. This, however, affects only the analyses in three dimensions, i.e., analyses of elevation patterns would, at this time, fail to be quantitative in nature. Also, the "complete" map of the quarry pit locations can only be considered a fair representation of the quarry pit array at the Alibates Quarry. In summary, this effectively means that only points mapped from each *individual* mapping station can be compared together—each set of mapped points (from the other mapping stations) is independent and cannot be compared or related to the others. This is because each mapping station was given a coordinate of (0,0), and the backsight angle/azimuth is unknown, and possibly different, for each station and cannot, therefore, be effectively checked or corrected.

After re-entering all of the reported data points into a Microsoft Excel spreadsheet, reported declination errors were applied to them using the NGDC calculator mentioned above. Next, using an online calculator, these corrected latitude/longitude readings were converted to UTM coordinates (Mummery 2009). After conversion, the UTMs were scatter plotted on an XY axis and overlain on top of a map of the area found on Google Earth (Google 2009). This was used to test the plot's general fit to the landscape (Figure 5-2).

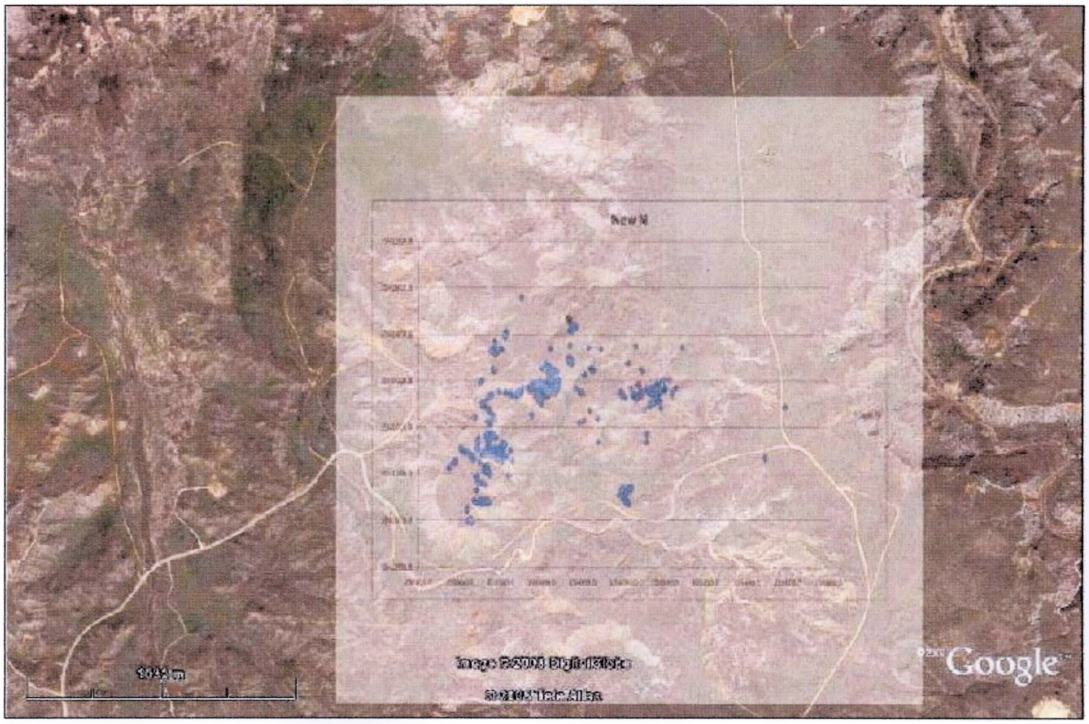


Figure 5-2. Test for data "fit" to landscape.

The author of this thesis undertook subsequent ground truthing of the Katz and Katz (1993b) corrected data and verified the above noted problems with the locational data recorded for both data stations and quarry pits. Each station was observed to be oriented several degrees and many meters from their reported locations on the ground. The offset for the ground truthed pits appeared to be 25 to 30 meters. However, the general spatial patterning of the pits appeared to be valid. Due to time constraints, only one set of pits, mapped from one mapping station were checked for accuracy--- however, this was for mapping station two, which was associated with the most pit locations.

The most appropriate types of spatial analysis were applied to the dataset: nearest neighbor analysis and cluster analysis (Whallon 1972, 1973, 1974, 1984). Nearest neighbor analysis uses the two-dimensional coordinates of each pit to determine the average distances between pits. In addition, this technique can be used to ascertain the relationships between each and every surveyed pit using any chosen correlate, i.e., by location and surface area. Cluster analysis was used to define the groupings of horizontal clusters by defined surface area classes. Cluster analyses can be performed using the TwoStep, Hierarchical, Multidimensional Scaling (MDS), or K-Means procedure. Each procedure employs a different algorithm for creating clusters and each has options not available in the others (Shennan 1997; SPSS 2007; Whallon 1972, 1973, 1974, 1984). MDS is the procedure used by ArcGIS software to output computations that were then superimposed, by the software, onto the base map of Alibates Quarries. The other mentioned procedures, TwoStep, Hierarchical and K-Means were not used as they are data reduction techniques that reduce a large number of cases to a small number of underlying clusters, i.e., they are procedures used to create clusters, not identify or analyze existing ones, and therefore not required for this thesis (Green et al. 1989). "The objective of MDS is to array points in multidimensional space such that the distances separating points physically on the scatter plots reflect as closely as possible the subjective distances obtained by surveying objects" (Garson 2009). MDS allows for the discovery of underlying similarities or distance judgments by "perceptual mapping" data onto objective scales, such as zones of influence in distance factors set by the researcher (Garson 2009; Green et al. 1989).

ArcGIS Data Preparation

Since the main objective of this thesis is the identification of patterning in the array of quarry pits at Alibates Quarry, it was most efficacious to integrate the data set into a GIS platform. Environmental Systems Research Institute, Inc. (ESRI) ArcGIS Desktop (2009) was chosen as the best software suite to perform the analysis as this software is capable of advanced statistical and spatial analysis and can visualize/output the results in high-quality maps. A colleague with knowledge of how to operate ArcGIS Desktop software, Chris Davis, was commissioned (as an unpaid volunteer) to create maps from the dataset as provided by the author of this thesis.

In order to create a surface area correlate for analysis, the noted morphological characteristics of each pit were more closely examined. It was noticed that some of the pits were noted as circles even though their recorded lengths and widths were not the same. Also noted were pits designated as elliptical that had nearly equivalent lengths and widths. Therefore, all of the pits were initially examined as both circles and ellipses, and the computed areas compared. Since there was little difference in computed area when seen as either circular or elliptical, and more were true ellipses than true circles, all pits were analyzed as ellipses, and their surface areas recorded in the main Excel spreadsheet along with their corrected locational information (as noted above). These data were then imported into the ArcGIS Desktop software and resolved into a map (Figure 5-3).

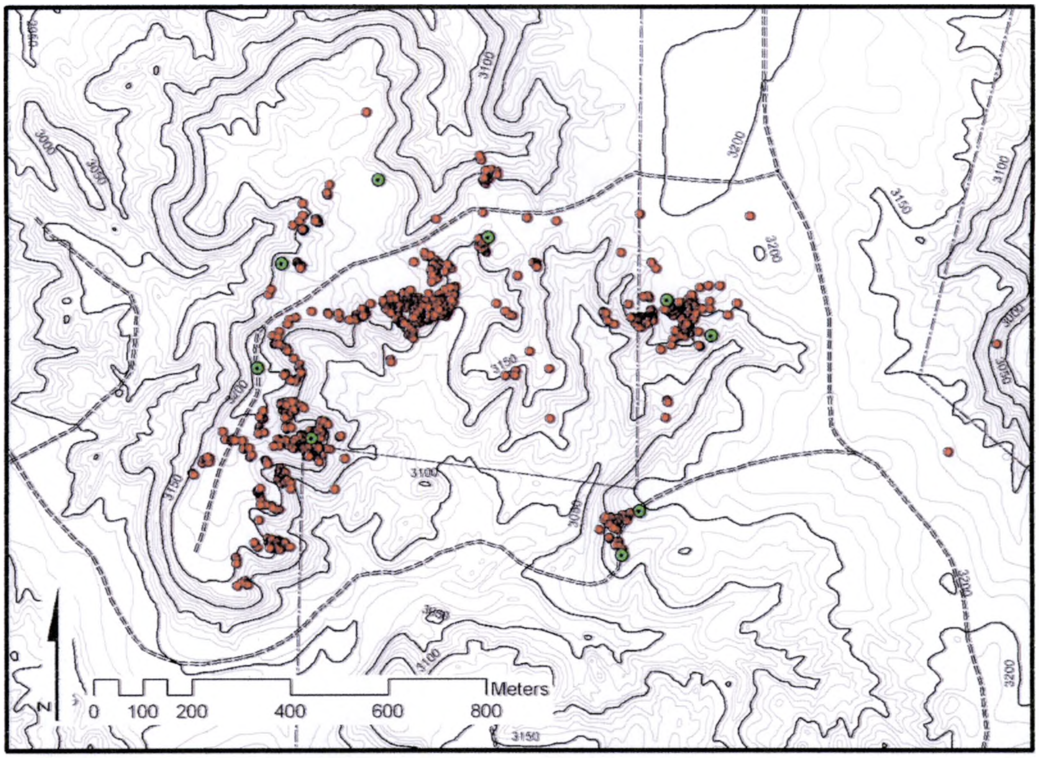


Figure 5-3. Overview map of all plotted quarry pits.
Points with dot-centers are data stations.

Based on a visual inspection of Figure 5-3, five areas were chosen to test for spatial patterning (Figure 5-4). Because of the errors in the Katz's teams surveying techniques (discussed earlier), care was taken to, whenever possible demarcate areas that contained points surveyed from a single mapping data station. Five of the Katz and Katz (1999a, 1999b) reported pit coordinates were deemed spurious, as they were located well outside of the survey boundary—they were not used in this study, leaving 729 "valid" pit locations for analysis. While it is true that more clusters might be available for testing, because of inconsistencies in the data between mapping stations, only Cluster Areas 1- 4, demarcated by boxes in Figure 5-4 were analyzed in order to initially test the models noted in Chapter IV (Figures 4-1, 4-2, and 4-3). This represents 82% of the 729 plotted pits, a significant sample. Cluster Area 5 was demarcated for use in ground truthing. Further research directions will be discussed in a later section of this document.

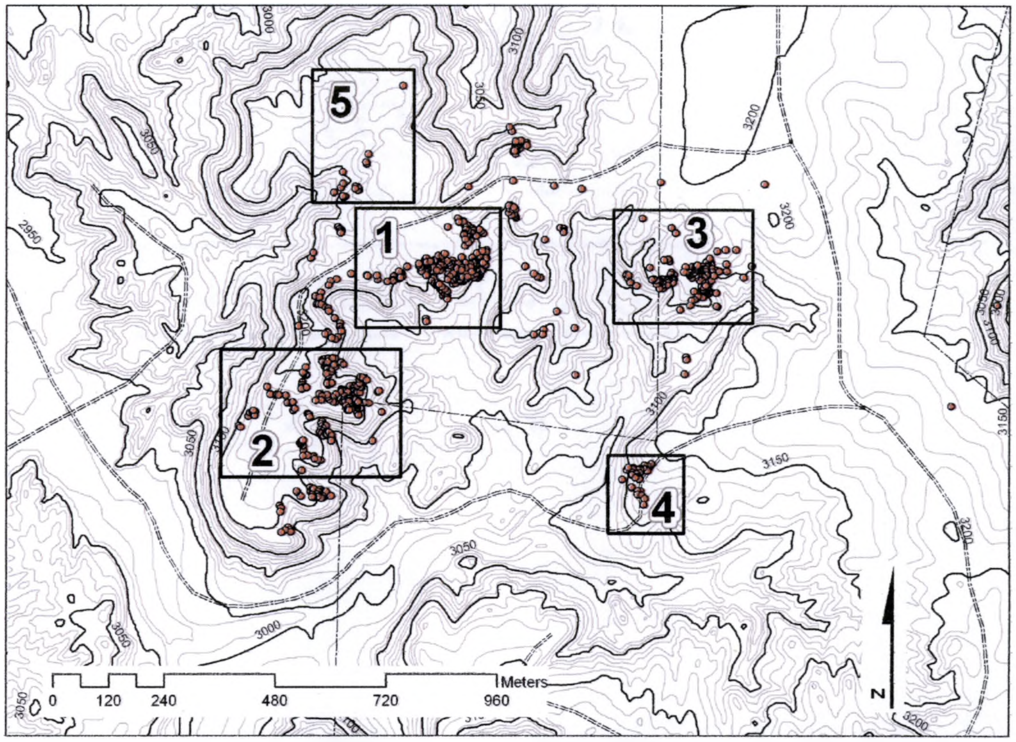


Figure 5-4. Numbered Cluster Areas of pits chosen for spatial analysis
Cluster Area 5 was used for ground truthing.

Once the areas to be examined were allocated, ArcGIS was used to do statistical cluster analysis, in order to determine the likelihood of where the observed clusters were located in a continuum from clustered through randomness to dispersion (even distribution). ArcGIS presented the results in both chart and histogram form (Table 6-1, for example).

CHAPTER VI

RESULTS AND ANALYSIS

Initially, average nearest neighbor distance analyses were performed on all of the cluster areas and the entire pit assemblage. The ArcGIS software presents the results of these tests as a scaled graphical representation of both relative clustering and randomness that denotes both significance levels and critical values. The results chart for the entire pit assemblage of 729 pits can be seen in Table 6-1 below. It is interesting to note that the overall spatial orientation of the quarry pits is statistically extremely clustered. The 729 pits are roughly enclosed within a 1000 m block and the computed *p*-value is zero, which negates the null hypothesis (that there is no clustering-- only a random dispersal of pits). The reported z-scores from ArcGIS, which relate a similar negation, are not as relevant, as the data for the pits is not really considered normalized—we do not know for sure if the Katz' team recorded all of the pits at Alibates Quarries. Only the reported *p*-values will be discussed in this thesis— *p*-values are confidence levels, as they rise in value from zero toward one, they become less reliable. Higher *p*-values might indicate the presence of some locational information that suffers from shift error due to poor surveying techniques. It is important to note that only Cluster Area 4 scored a value over

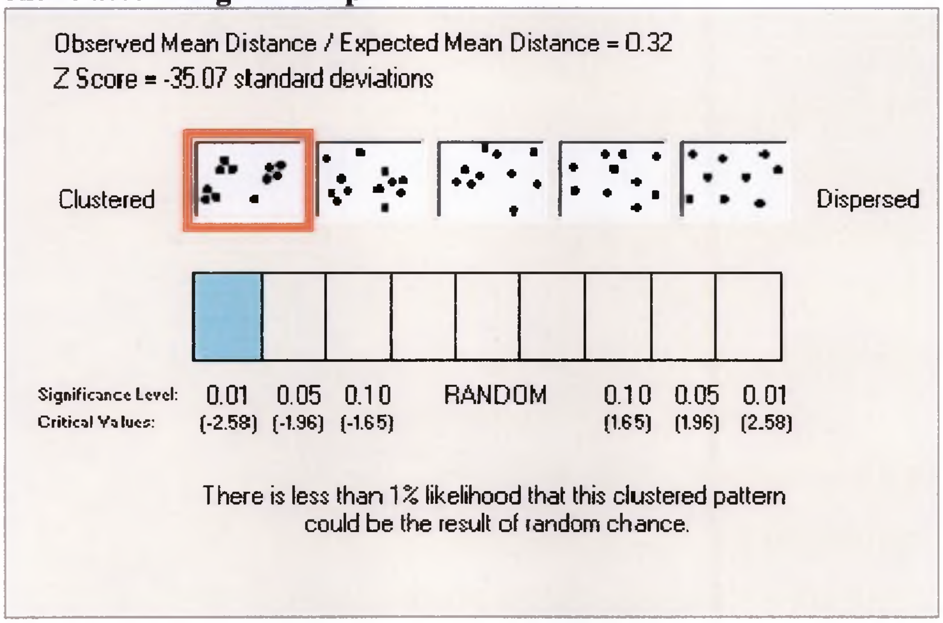
0.10. As will be shown, there is an overall high confidence level (0.07 or less) reported for all other Cluster Areas and their sub-clusters.

Also reported in Table 6-1 are the expected and observed mean distance values. These values are used to compute the Nearest Neighbor index, or ratio. This index is the ratio of the observed distance between points divided by the expected distance (ESRI 2009). The expected distance is the average distance between neighbors in a hypothetical random distribution (the demarked area of analysis). If the resultant computed index is less than one, the pattern exhibits clustering; if the index is greater than one, then the observed points trend toward random dispersion. Note that dispersion is not the same as randomness (Table 6-1) (ESRI 2009).

Of course, the observed activity pattern for the aggregate of all pits as extremely clustered would be expected in an area where quarrying is being undertaken, as the pits would tend to be concentrated in areas where the desired materials were bedded, and/or outcropped. Other biases to be noted when looking at the entire assemblage of pits are from the errors in the way the points were located—as noted earlier, they were mapped using different mapping data stations and this would result in orientations that would shift from true between sets of points located by different mapping data stations.

Statistical analysis of the surface area dataset (which included the entire 729 pit assemblage) revealed that, within one standard deviation, the pits could be classed into four intervals, or classes (Table 6-2). In order to discern finer patterning, pit Cluster areas (Figure 5-7) were delineated and then analyzed to see if pits of the four different surface area classes exhibited any spatial patterning. As noted earlier, an effort was made to create Cluster Areas that were comprised of points mapped by individual mapping stations. ArcGIS produces maps that represent pits with buffers, or “zones of influence” around them. Pits of different size classes are represented as circles of varying diameters and in four different colors for easier visibility. This thesis seeks to identify the form and extent of any zone patterning that might be present.

Table 6-1. Average nearest neighbor analysis for entire assemblage of 729 pits.



Average Nearest Neighbor Summary
Pit Count: 729
Observed Mean Distance: 7.303 **Expected Mean Distance:** 22.745259
Nearest Neighbor Ratio: 0.321092 **p-value:** 0.000000

Table 6-2. Pit Classes by Surface Area.

Class #, size	Surface Area Range (m^2)
1, small	0.16 - 4.63
2, small	4.63 - 10.15
3, large	10.15 - 15.67
4, large	15.67 – 76.42

Cluster Area 1

Cluster Area 1 (Figure 6-1) contained the largest sample of quarry pits: 234. The *p*-score (0.000) for this Cluster Area indicated extensive clustering (Table 6-3). An examination of pit buffer zones reveals that even when all pit size classes are represented (Figure 6-2), only four pits fall outside of the largest 10 meter buffer zones of nearby pits. When only the two smallest surface area pit classes are represented (Figure 6-3), there is an interesting pattern of consistent 5 meter gaps between similar sized pits. There are also many pits exhibiting near-linear alignment.

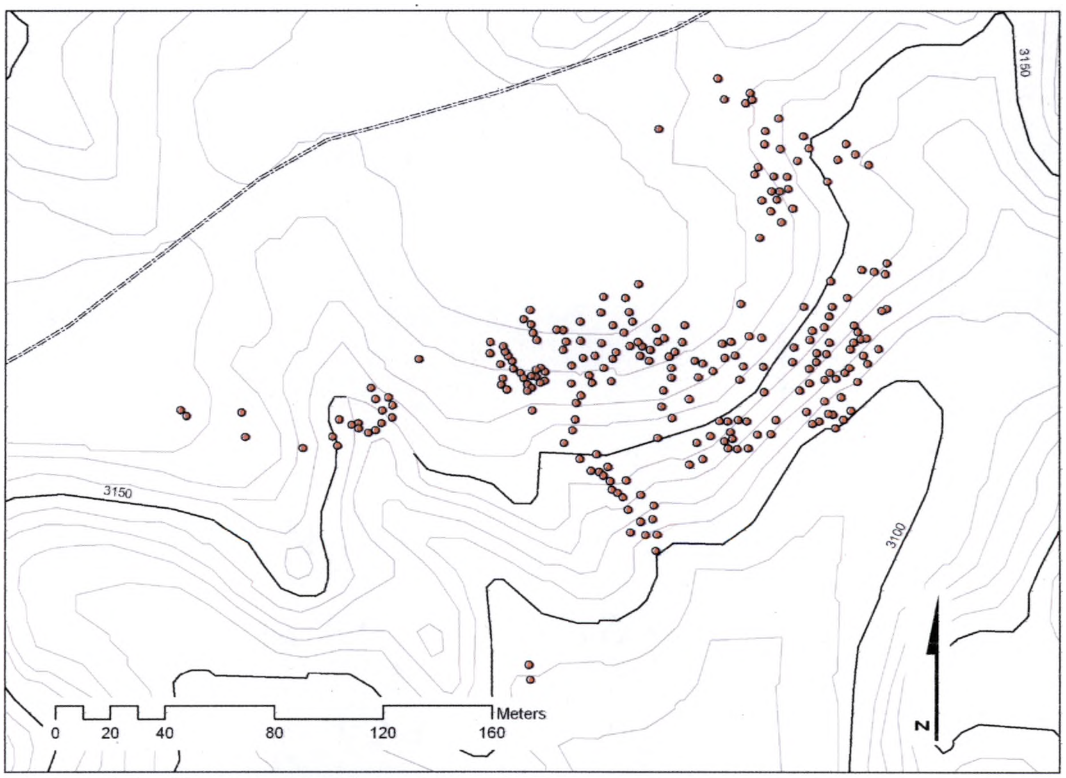
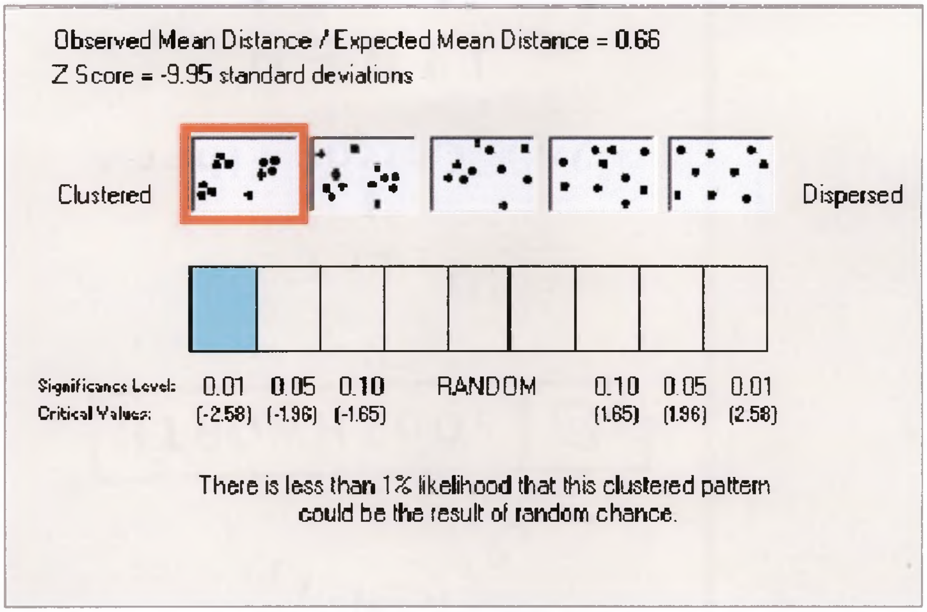


Figure 6-1. Cluster Area 1.

Table 6-3. Average nearest neighbor analysis for Cluster Area 1.



Average Nearest Neighbor Summary
Pit Count: 234
Observed Mean Distance: 4.313870 **Expected Mean Distance:** 6.535601
Nearest Neighbor Ratio: 0.660057 **p-value:** 0.000000

The underlying pattern of consistent buffering seen in these pits, and other clusters in the study, could have been caused by the bounding of the cluster zone (averaging out, or rounding off of small distances between the pits—a function of the math involved), or could be a factor of the overall resolution of the map, or a limitation in the software's ability to visualize the zones. The point here being that recognizing these patterns, even with their statistical validation, adds nothing toward their explanation, or validating them in the real world.

Perhaps more interesting to note, is how the largest two classes of pits seem to intrude upon the buffer zones between the smaller pits, and overlap many of them—compare Figures 6-2 and 6-3. This is a pattern that will be seen in all Cluster Areas under study, except Cluster Area 4 (Cluster Area 5 was used for ground truthing only). If the clustering and buffering are valid, then the intrusions could indicate a shift in the way mining was done. However, the meaning of this pattern is not clear at this time.

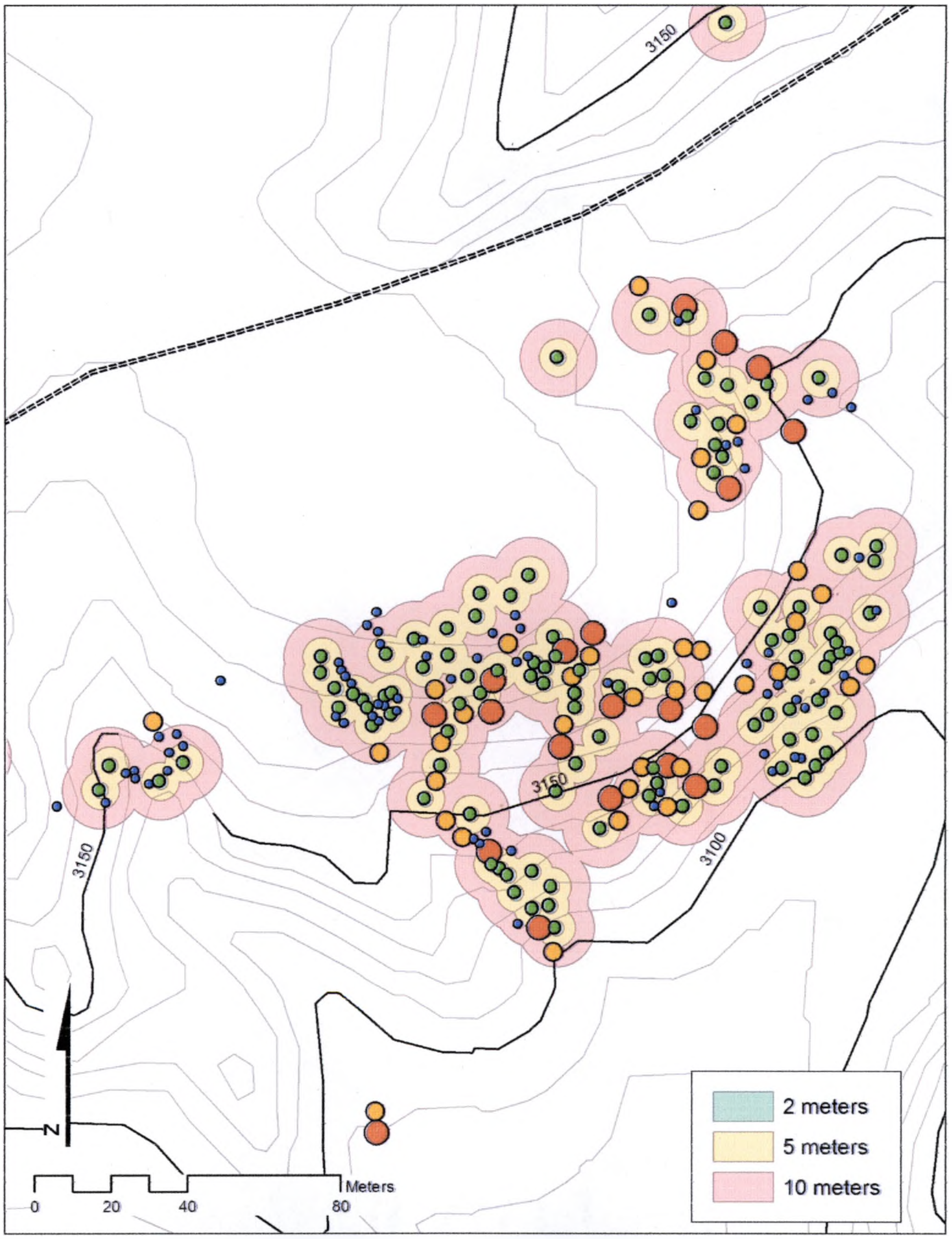


Figure 6-2. Cluster Area 1 showing pit buffer zones for all size classes. Blue and green dots represent smallest surface area pits; red and orange represent largest surface area pits.

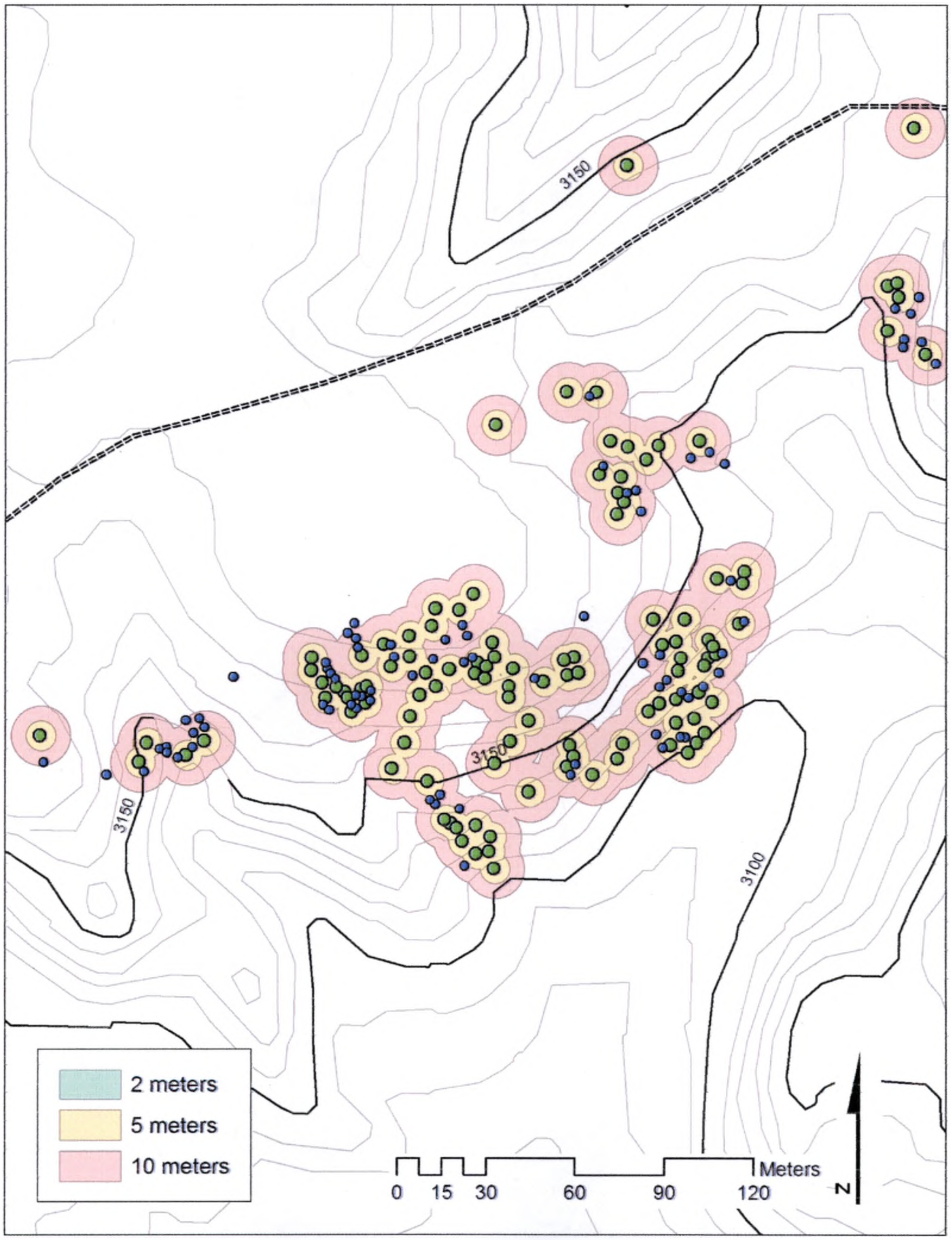


Figure 6-3. Cluster Area 1 showing pit buffer zones for two smallest size classes. Blue and green dots represent smallest surface area pits.

Cluster Area 2

Cluster Area 2 (Figure 6-4) is composed of 187 quarry pits. The reported *p*-value of 0.00 relates a high degree of confidence that this Cluster Area is non-random and highly patterned by segregated clusters (Table 6-4).

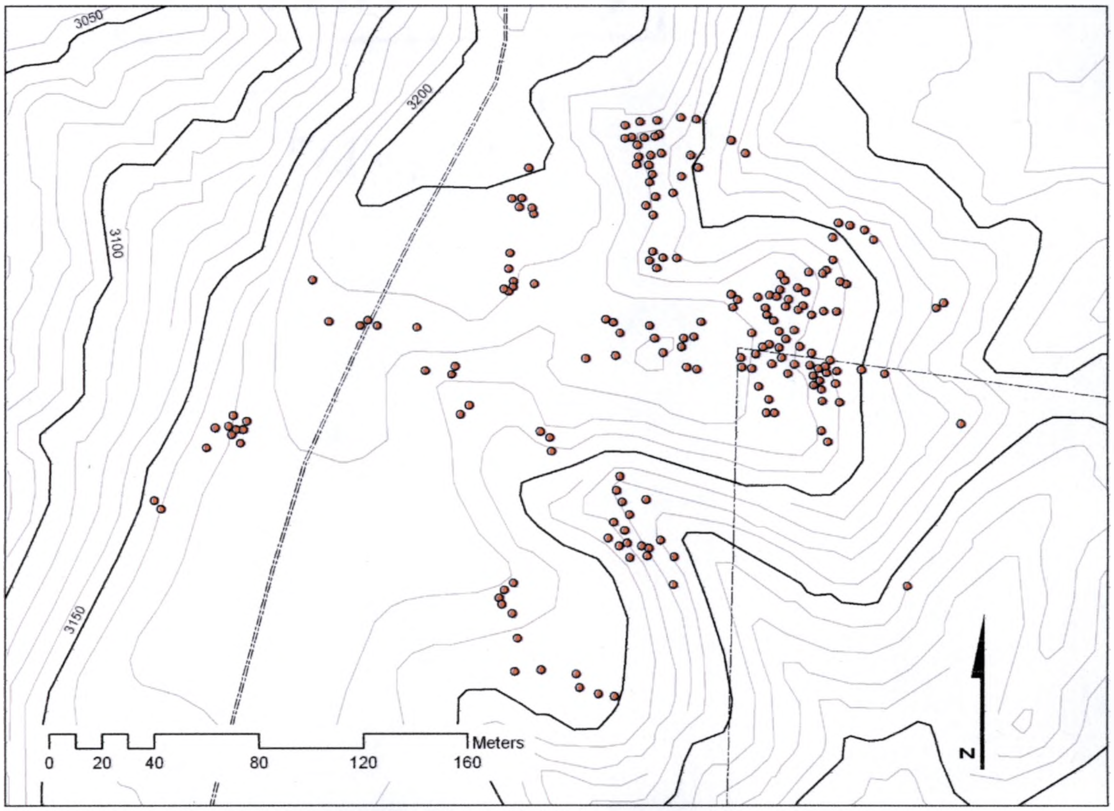
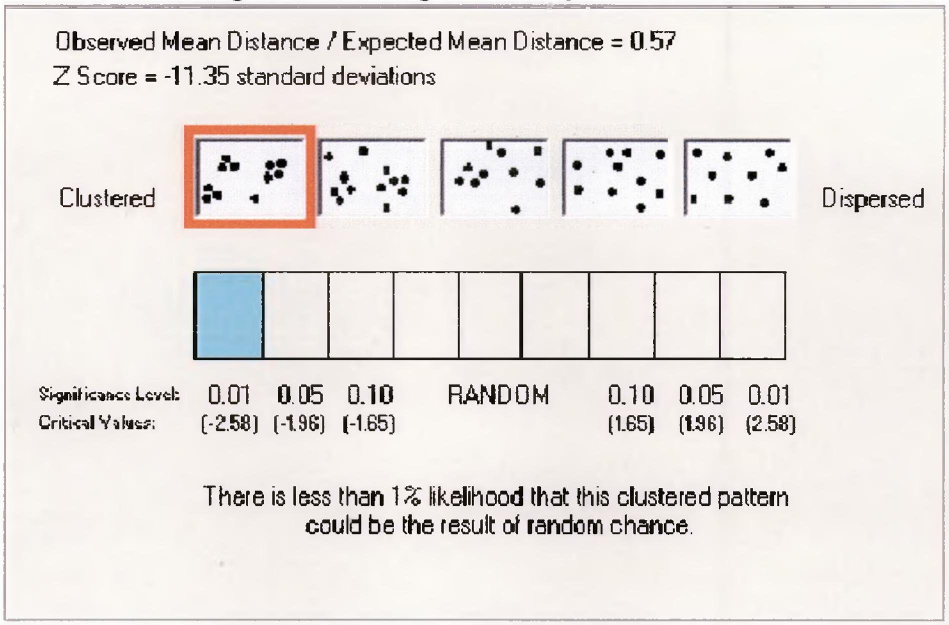


Figure 6-4. Cluster Area 2 showing all 187 quarry pits.

Table 6-4. Average nearest neighbor analysis for Cluster Area 2.



Average Nearest Neighbor Summary
Pit Count: 187
Observed Mean Distance: 5.098289 **Expected Mean Distance:** 9.003990
Nearest Neighbor Ratio: 0.566225 **p-value:** 0.000000

A further examination of Cluster Area 2 shows that pit buffer zones around all size classes fall into the same pattern as Cluster Area 1: 98% of all pits are located within a 10 meter zone of some other pit (Figure 6-5). The same percentage of pits falls within five meter zones of each other. Figure 6-6 illustrates that 93% of the two smallest size classes are within 10 meters of each other: three of the smallest pits exhibit anomalous patterning, showing up at an approximate 20 meter range from the main cluster area. In this Area, 79% of the larger pits present impinge upon areas where there are smaller pits. Twenty-two of the two large classes of pits, create their own independent groupings, free of smaller pits. These areas would be somewhat anomalous when compared to the other Cluster Areas, especially given the low *p*-value for the Area. More resolution was needed, so sub-clusters were demarked to try and enclose areas within Cluster Area Two.

These sub-cluster areas (2A (45 pits), 2B (87 pits), 2C (33 pits), and 2D (22 pits)) were allocated by visual inspection, as "natural" boundaries seemed to be present in the array (Figure 6-7).

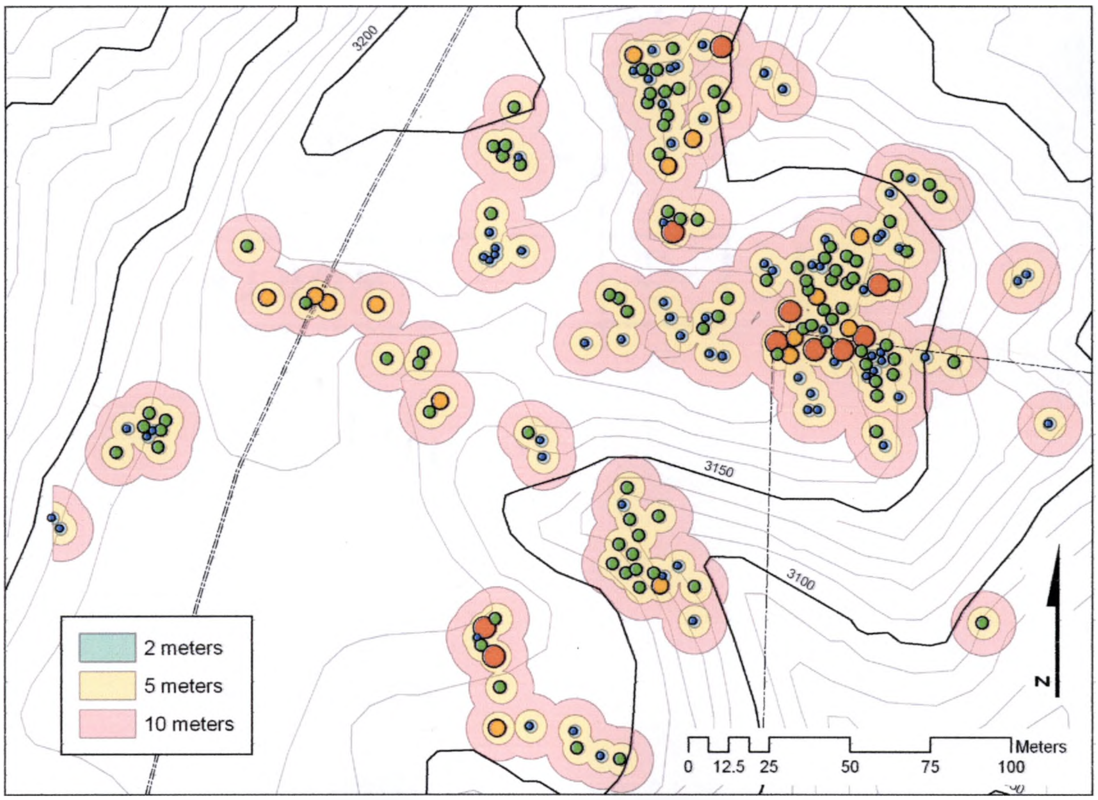


Figure 6-5. Cluster Area 2 showing pit buffers for all size classes.
Blue and green dots represent smallest surface area pits; red and orange represent largest surface area pits.

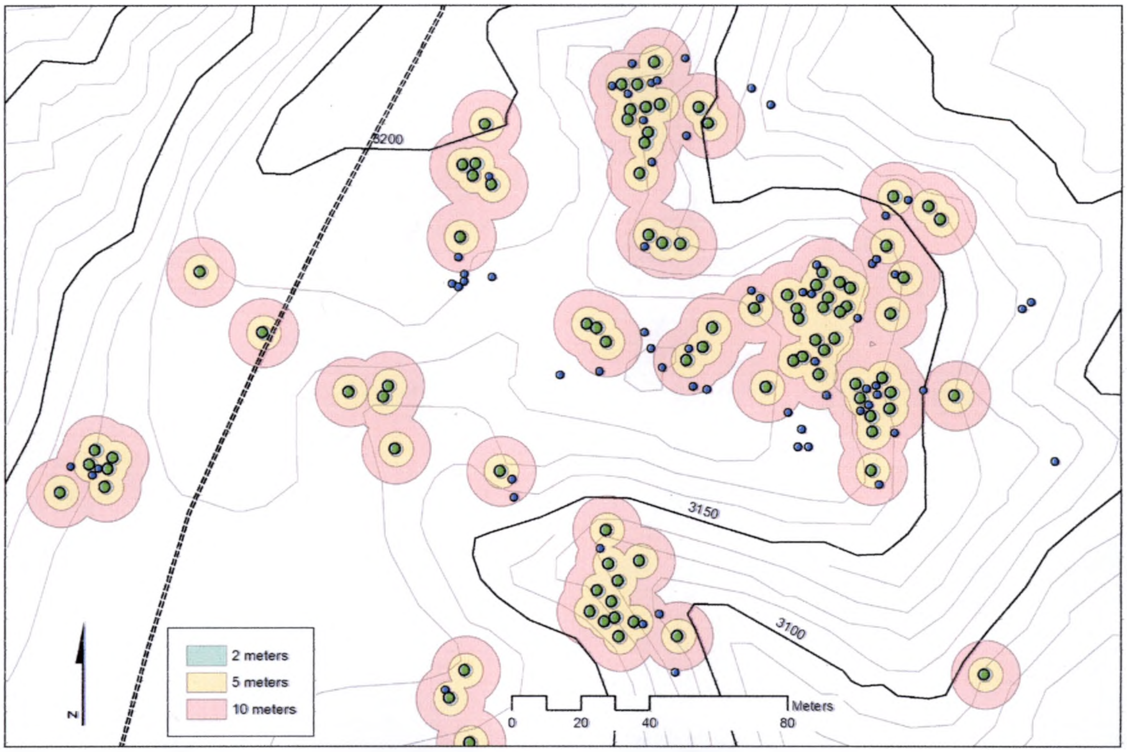


Figure 6-6. Cluster Area 2 pit buffers for two smallest pit size classes.
Blue and green dots represent smallest surface area pits.

P-values for the four sub-clusters vary. Interestingly, the clusters containing the majority of small pit classes (all but 18), 2A and 2B, have the lowest *p*-values at 0.007 and 0.00009, respectively, and are considered highly clustered (Tables 6-5 and 6-6). Sub-clusters 2C and 2D have higher *p*-values (0.07 and 0.28, respectively), though not significantly so, in that they are still very close to 0.0, but are less clustered that 2A and 2B. Accordingly, while nearest neighbor ratios for 2A, 2B and 2D are low (all three at near 0.79), the ratio for 2C, at 1.09, indicates that the observed patterns might be random. When contrasted with the reported *p*-values for the sub-clusters, there is less confidence in the reported nearest neighbor analysis for 2C (*p*-value=0.28) than the other sub-clusters in Cluster Area 2. Sub-cluster area 2C likely contains errors from the survey. Of note is the fact that these clusters contain only 13 of the small classes of pits out of a total of 55 pits, and perhaps indicate more of a pattern associated with larger pit classes, or perhaps an expansion of the main clustering in sub-clusters 2A and 2B, which together contain 73% of the pits in Cluster Area 2. However, the lower *p*-values for 2C and 2D might also indicate some error associated with the surveying and mapping of this area.

Of the four sub-clusters of Cluster Area 2, sub-clusters 2A and 2B show the highest degree of zone patterning within a 10 meter radius (Tables 6-4 and 6-5; Figures 6-8 to 6-11). There are three outliers (out of 87 pits) in 2B, while all pits in 2A fit within 10 meter zones. Note that large pits impinge upon small pit buffer zones. Pits in sub-cluster 2C would appear to fit within 10 meter zones, while 2D shows but one small pit outlier (out of 22): however, note the comment above regarding their *p*-values (Tables 6-7 and 6-8; Figures 6-12 to 6-15). In 2C and 2D, large pits impinge neatly between isolated small pits, creating 10 meter zones; the reason for this is unknown.

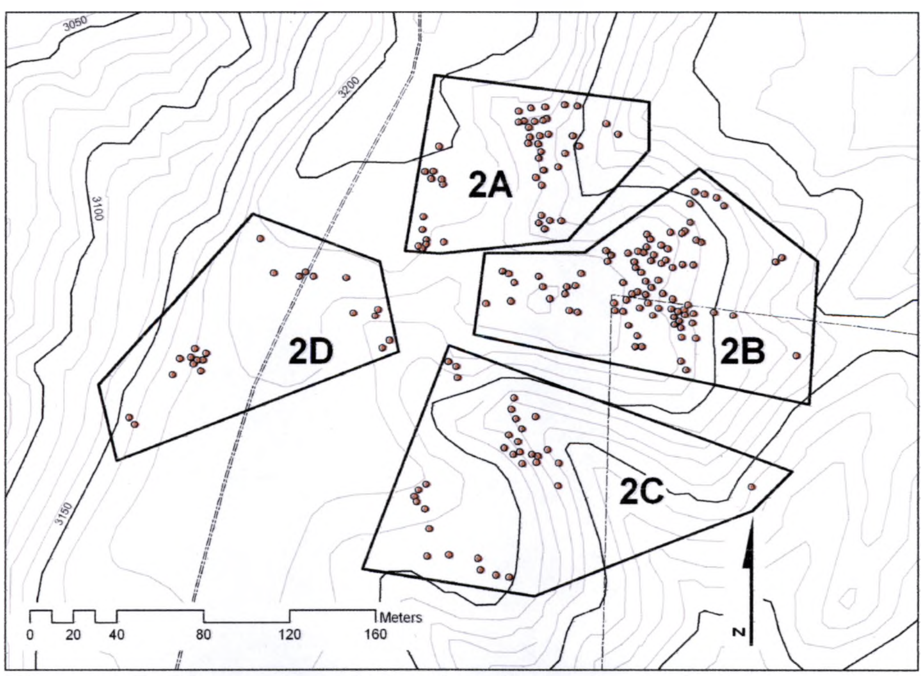
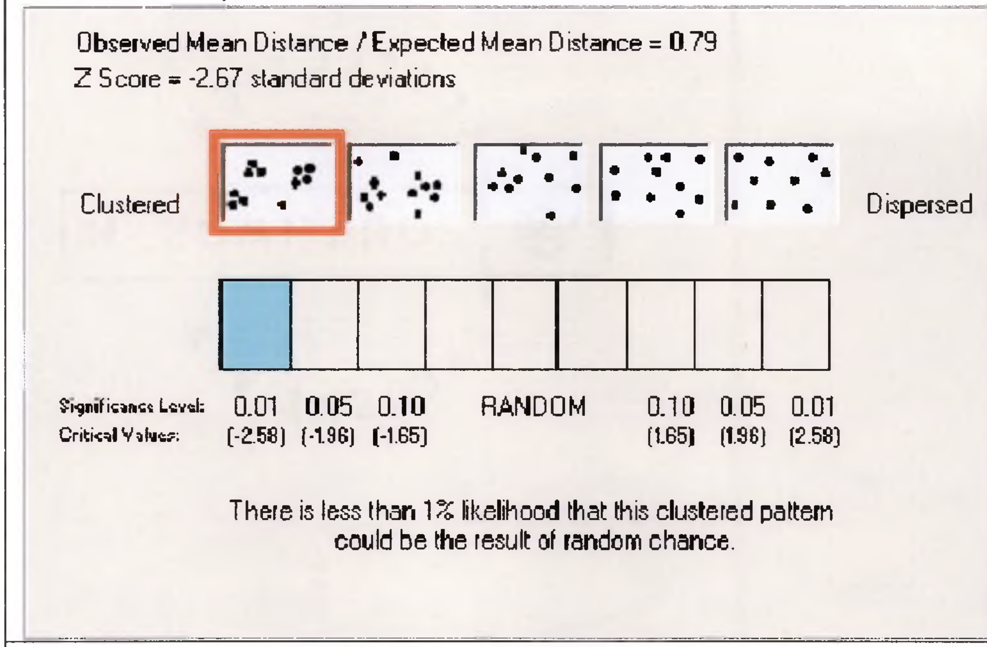


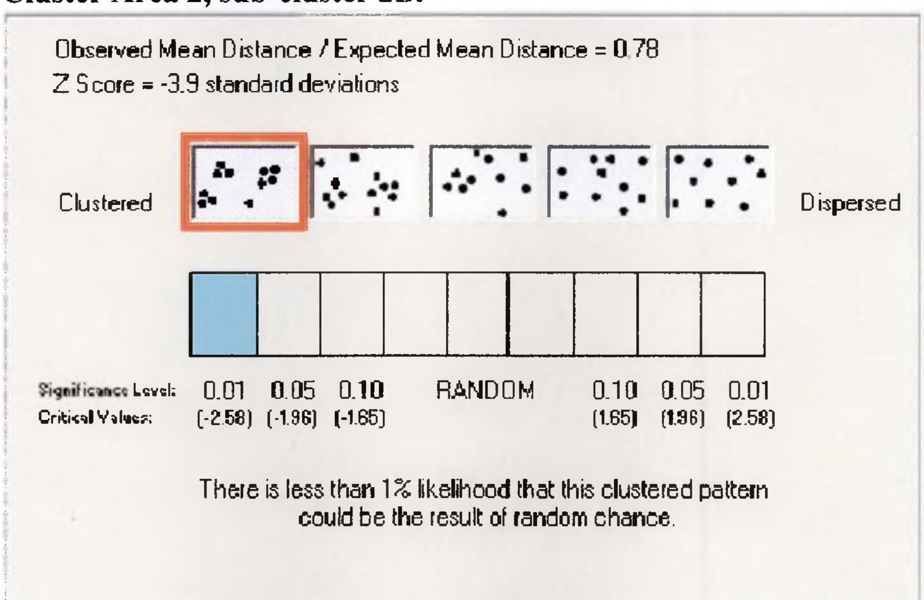
Figure 6-7. Cluster Area 2 showing denoted sub-clusters.

Table 6-5. Average nearest neighbor analysis for Cluster Area 2, sub-cluster 2A.



Average Nearest Neighbor Summary
Pit Count: 45
Observed Mean Distance: 4.410012 **Expected Mean Distance:** 5.570245
Nearest Neighbor Ratio: 0.791709 **p-value:** 0.007516

Table 6-6. Average nearest neighbor analysis for Cluster Area 2, sub-cluster 2B.



Average Nearest Neighbor Summary
Pit Count: 87
Observed Mean Distance: 4.475169 **Expected Mean Distance:** 5.726240
Nearest Neighbor Ratio: 0.781520 **p-value:** 0.000097

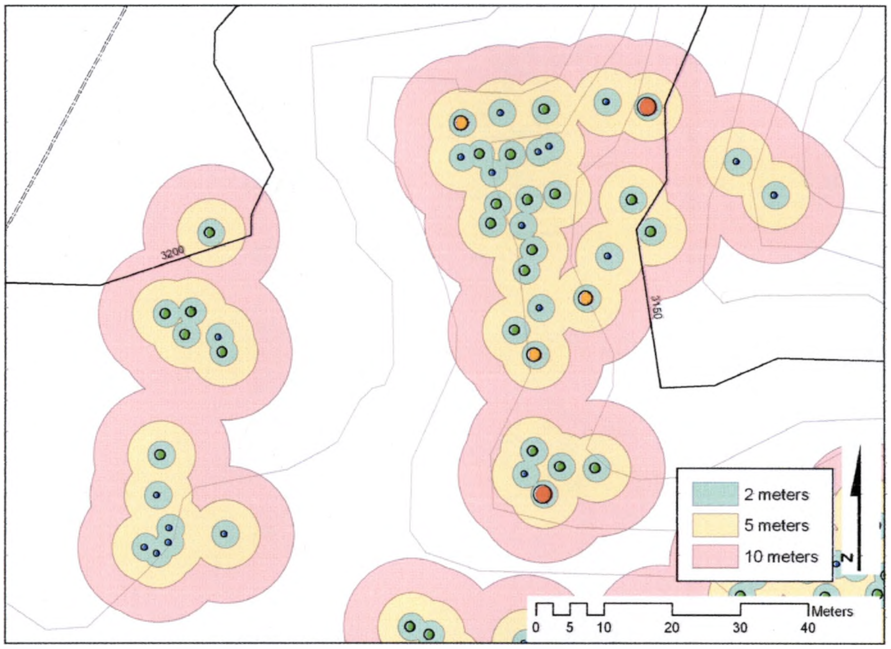


Figure 6-8. Cluster Area 2, sub-cluster 2A, showing all pit classes and their buffer zones. Red dots indicate large pit class.

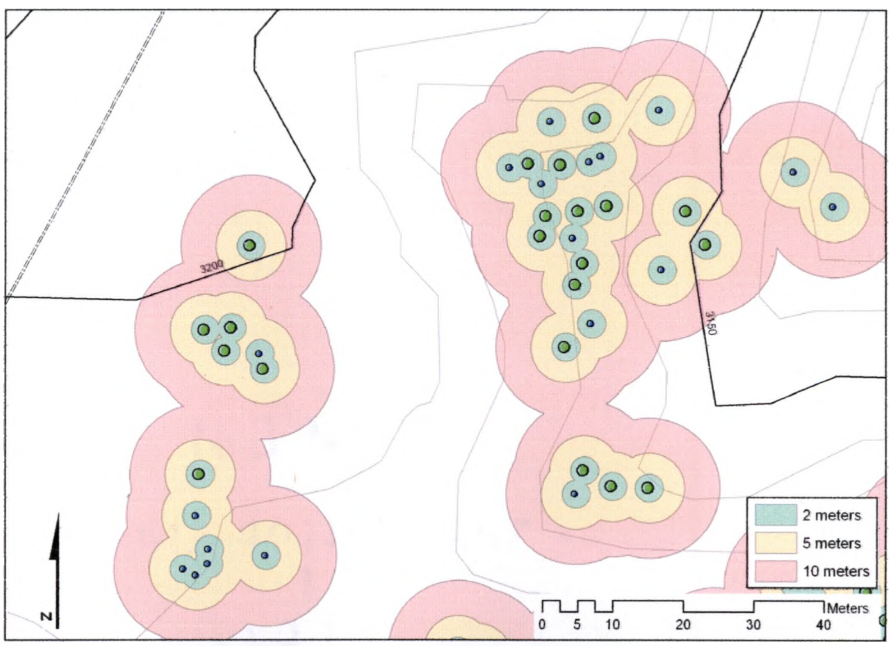


Figure 6-9. Cluster Area 2, sub-cluster 2A, showing small pit classes and their buffer zones. Blue and green dots represent small pit classes.

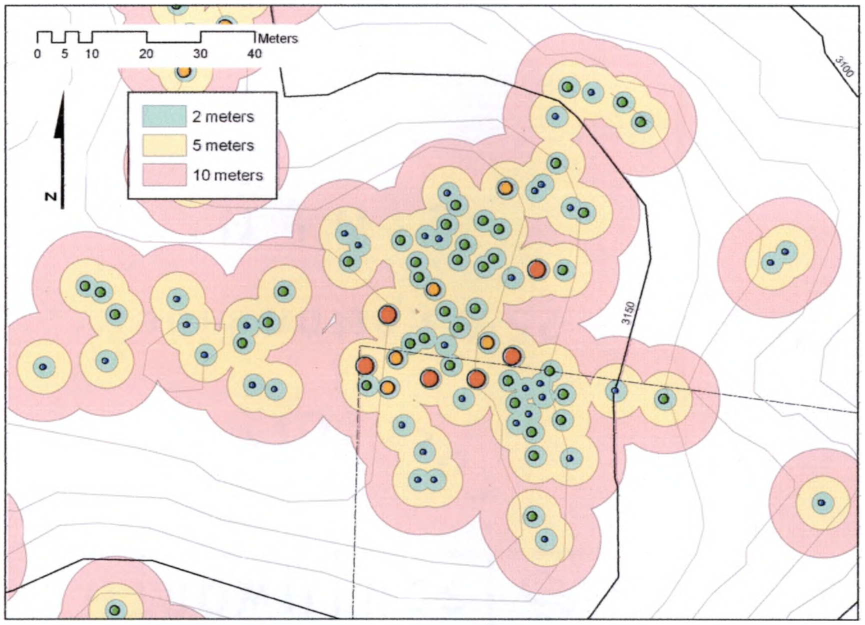


Figure 6-10. Cluster Area 2, sub-cluster 2B, showing all pit classes and their buffer zones. Red and orange dots represent large pit classes; blue and green dots represent small pit classes.

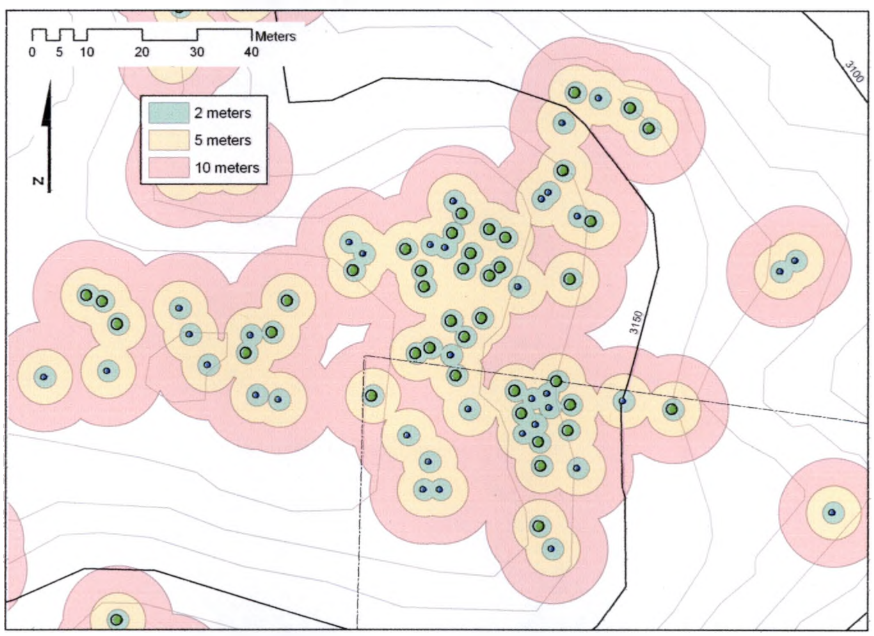
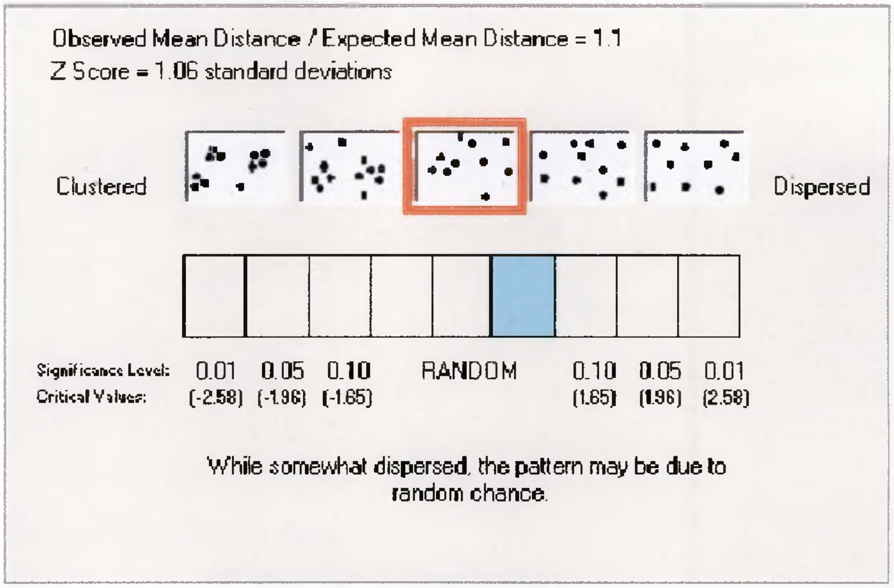


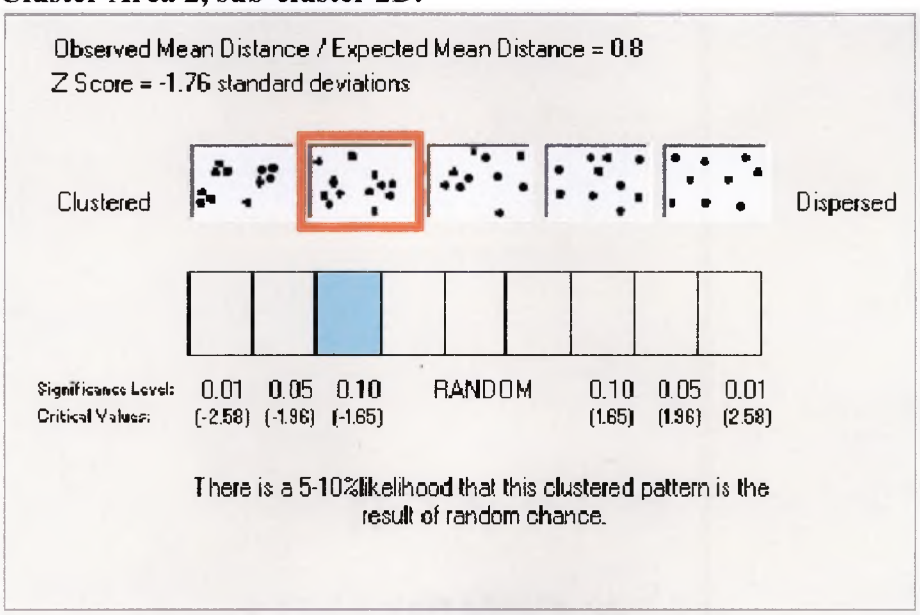
Figure 6-11. Cluster Area 2, sub-cluster 2B, showing small pit classes and their buffer zones. Blue and green dots represent small pit classes.

Table 6-7. Average nearest neighbor analysis for Cluster Area 2, sub-cluster 2C.



Average Nearest Neighbor Summary
Pit Count: 33
Observed Mean Distance: 8.020161 **Expected Mean Distance:** 7.312392
Nearest Neighbor Ratio: 1.096790 **p-value:** 0.287464

Table 6-8. Average nearest neighbor analysis for Cluster Area 2, sub-cluster 2D.



Average Nearest Neighbor Summary
Pit Count: 22
Observed Mean Distance: 5.804995 **Expected Mean Distance**: 7.224156
Nearest Neighbor Ratio: 0.803553 **p-value**: 0.077945

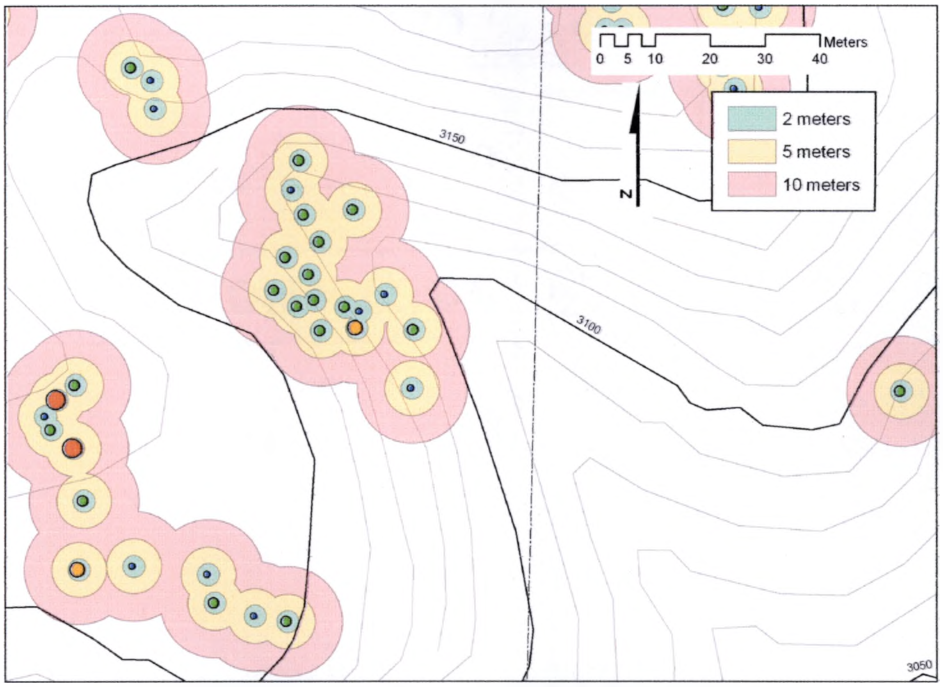


Figure 6-12. Cluster 2, sub-cluster 2C, showing all pit classes and their buffer zones. Red and orange dots represent larger pit classes.

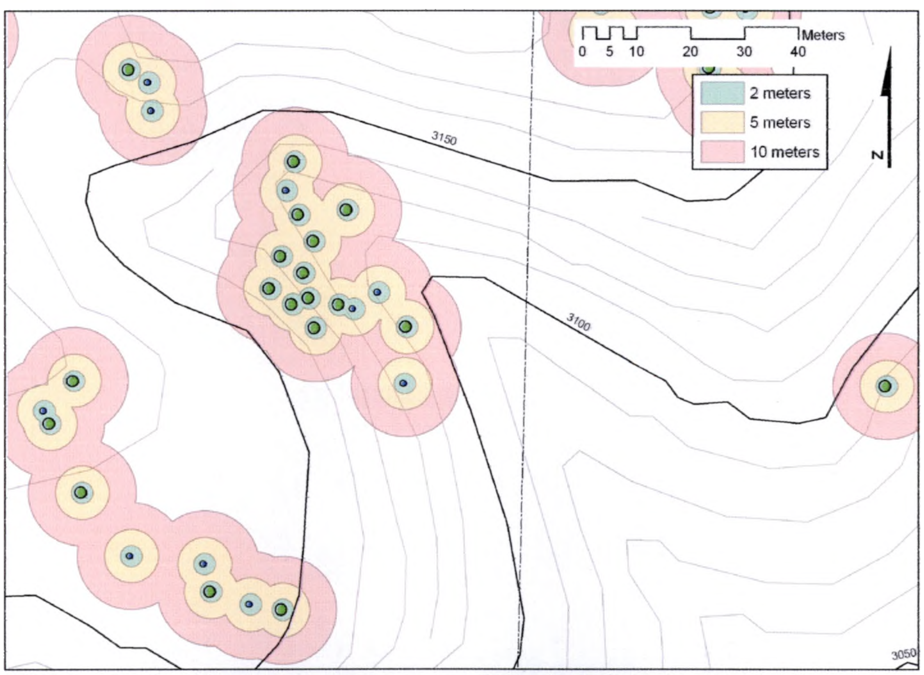


Figure 6-13. Cluster 2, sub-cluster 2C, showing small pit classes.

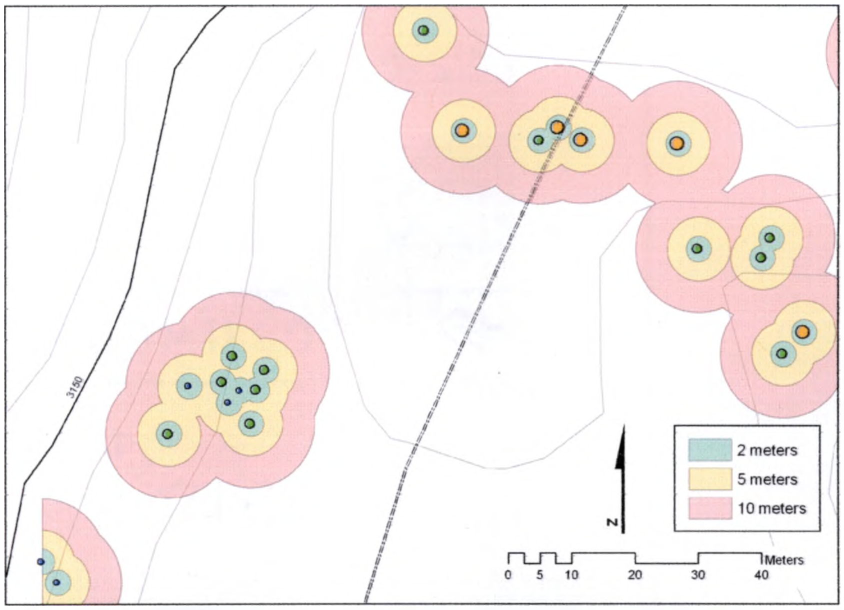


Figure 6-14. Cluster 2, sub-cluster 2D, showing all pit size classes and their buffer zones. Red and orange dots represent larger pit classes.

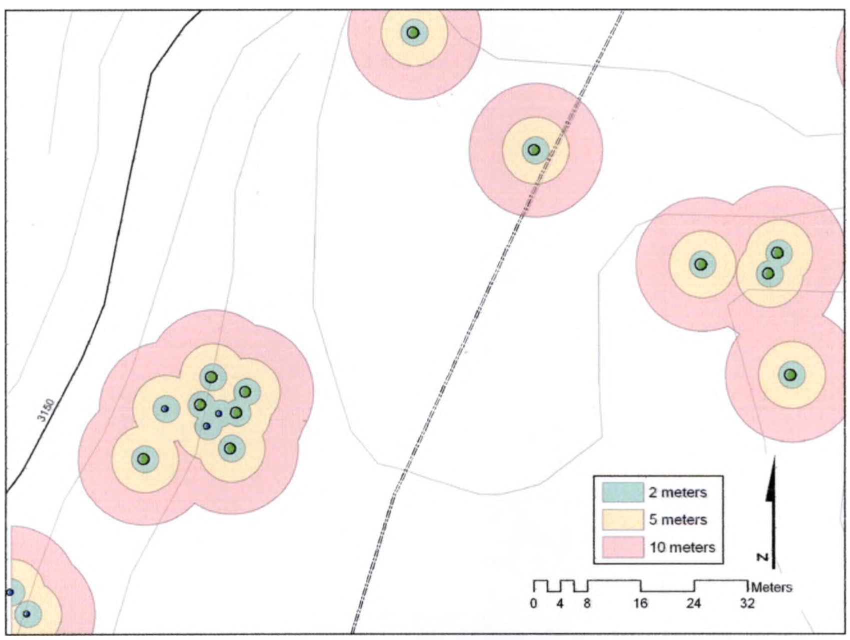


Figure 6-15. Cluster 2, sub-cluster 2D, showing small pit size classes and their buffer zones.

Cluster Area 3

Cluster Area 3 is composed of 128 quarry pits (Figure 6-16). The *p*-value for Cluster Area 3 is 0.000001, thus indicating a high confidence that the pits are clustered and not random (Table 6-9). The nearest neighbor ratio (0.79) indicates that the pits trend toward being clustered (Table 6-9). Ninety-two percent of the small pits and 96% of the large pits fall within 10 meter zones of each other, in other words, 88% of the pits in Cluster Area 3 are within 10 meters of another pit (Figure 6-17). This also means that 96% of all large class pits impinge upon smaller pits or small pit zones. A plotting of only the two smallest pit size classes also shows the same patterning; 92% of these pits are within 10 meters of each other (Figure 6-18).

Two sub-clusters were delineated by visual inspection (as described above) for Cluster Area 3, designated as sub-clusters 3A (87 pits) and 3B (41 pits) (Figure 6-19). Sub-clusters, 3A and 3B (Tables 6-10 and 6-11, Figure 6-20 to Figure 6-23), have reported high confidence *p*-values of 0.01, and nearly identical nearest neighbor ratios of ~0.85 and are therefore not as clustered as sub-clusters 2A and 2B (Tables 6-5 and 6-6).

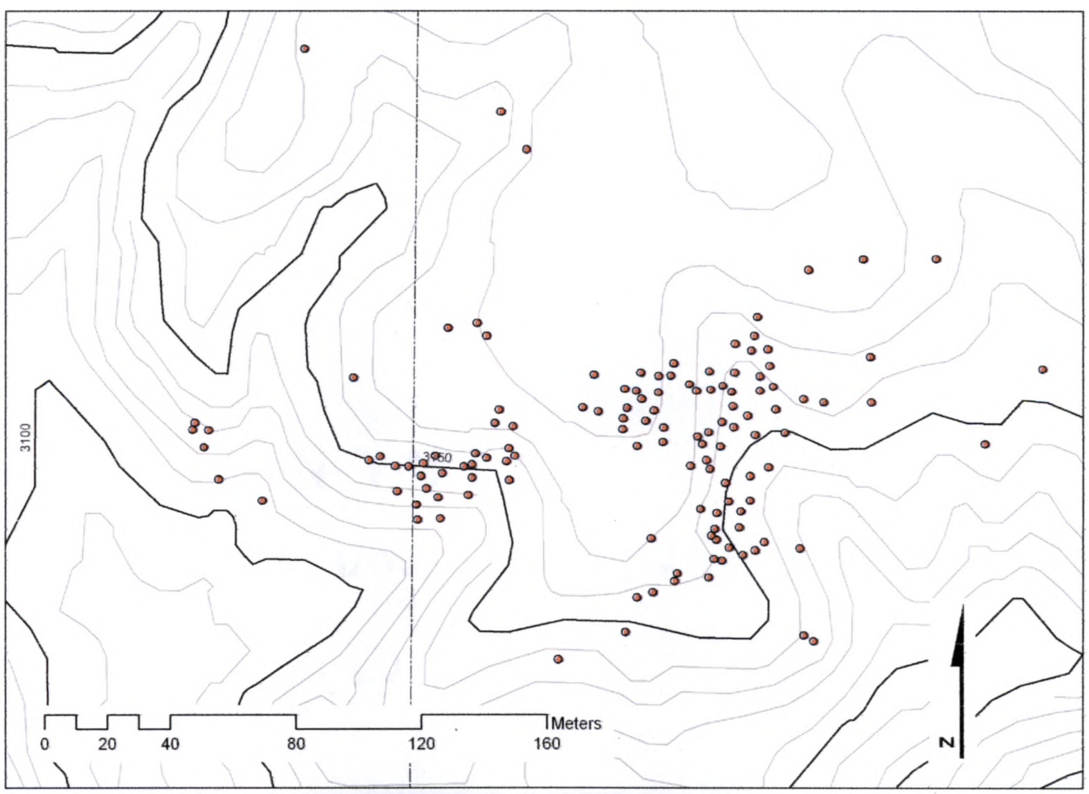
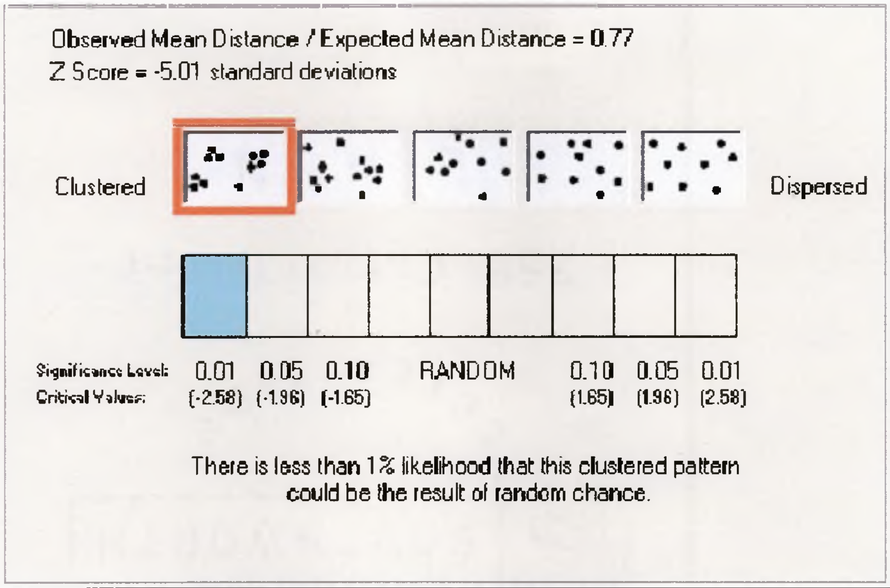


Figure 6-16. Cluster Area 3 showing all 128 quarry pits.

Table 6-9. Average nearest neighbor analysis for Cluster Area 3.



Average Nearest Neighbor Summary
Pit Count: 128
Observed Mean Distance: 6.726059 **Expected Mean Distance**: 8.754509
Nearest Neighbor Ratio: 0.768297 **p-value**: 0.000001

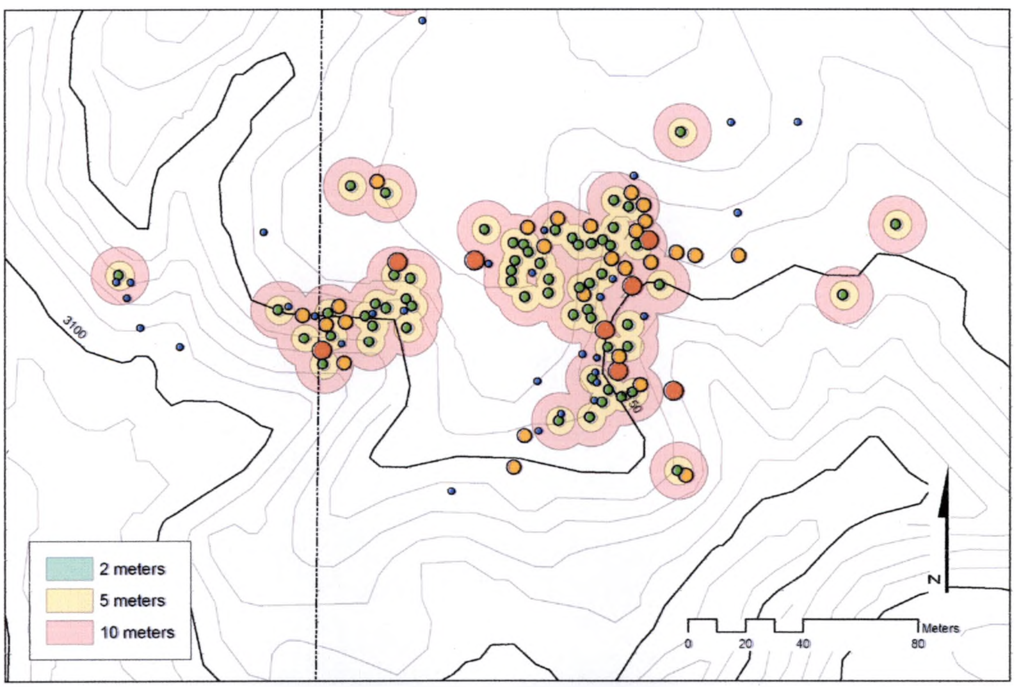


Figure 6-17. Cluster Area 3, showing all pit classes and their buffer zones. Red and orange dots represent large pit classes; blue and green dots represent small pit classes.

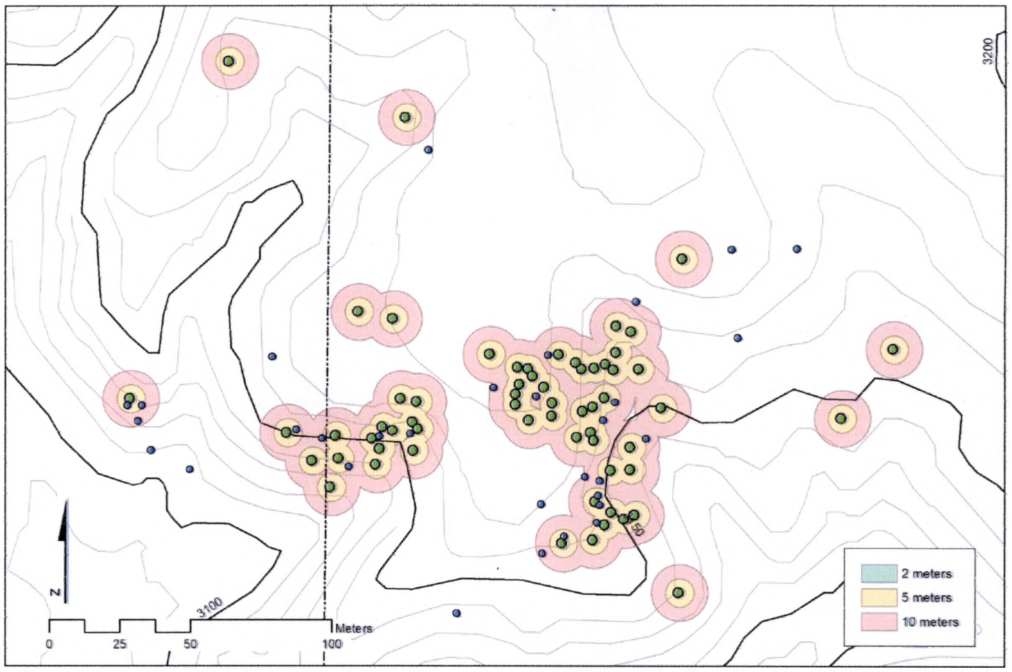


Figure 6-18. Cluster Area 3, showing the two smallest pit size classes and their buffer zones. Blue and green dots represent small pit size classes.

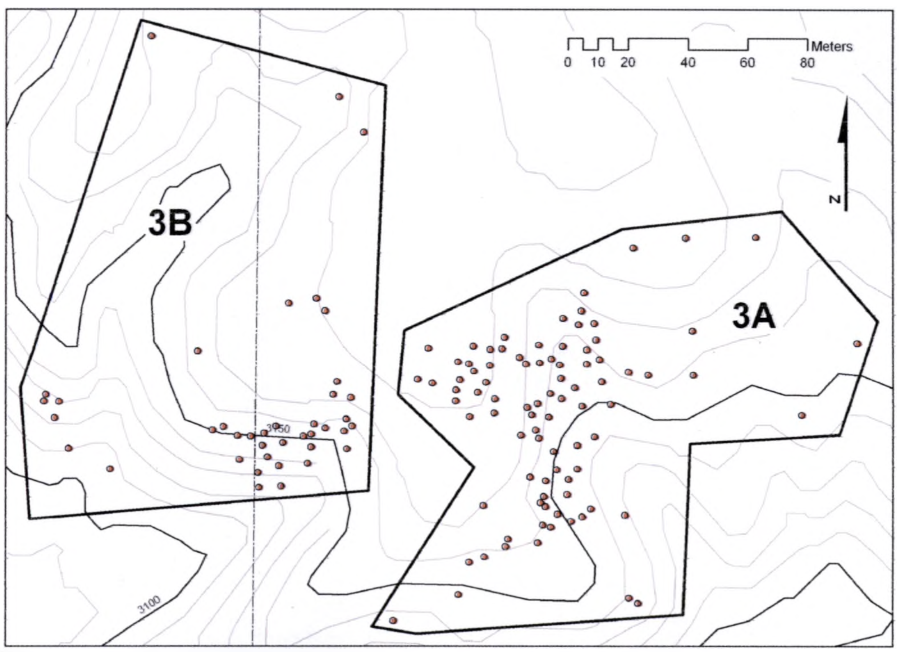
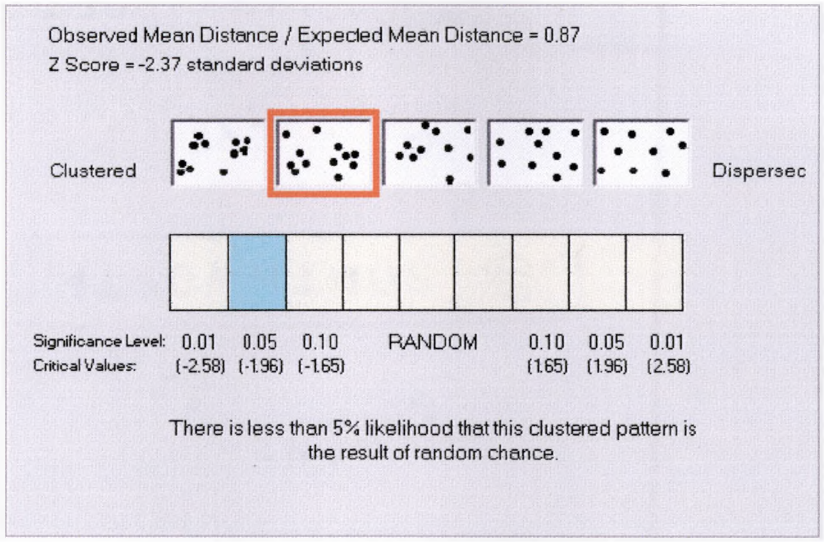


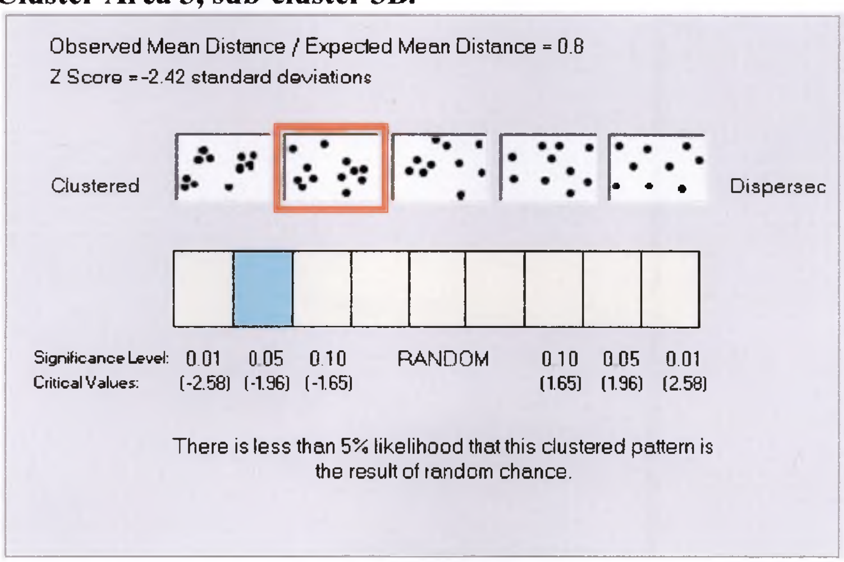
Figure 6-19. Cluster Area 3, showing the two delineated sub-clusters, 3A and 3B.

Table 6-10. Average nearest neighbor analysis for Cluster Area 3, sub-cluster 3A.



Average Nearest Neighbor Summary
Pit Count: 87
Observed Mean Distance: 6.451899 **Expected Mean Distance:** 7.440414
Nearest Neighbor Ratio: 0.867142 **p-value:** 0.017754

Table 6-11. Average nearest neighbor analysis for Cluster Area 3, sub-cluster 3B.



Average Nearest Neighbor Summary
Pit Count: 41
Observed Mean Distance: 7.307814 **Expected Mean Distance:** 9.108277
Nearest Neighbor Ratio: 0.802327 **p-value:** 0.015460

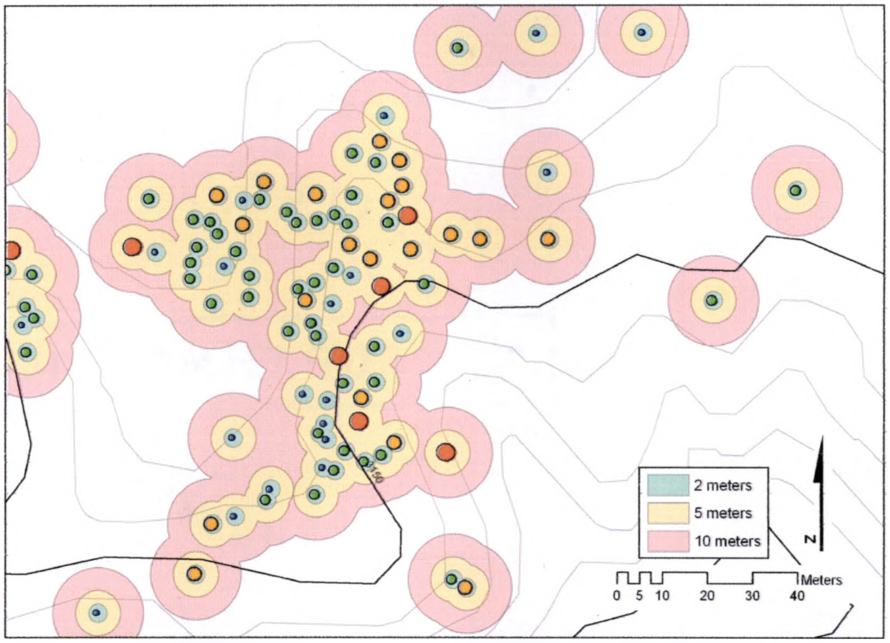


Figure 6-20. Cluster Area 3, sub-cluster 3A, showing all pit classes and their buffer zones. Red and orange dots represent large pit classes; blue and green dots represent small pit classes.

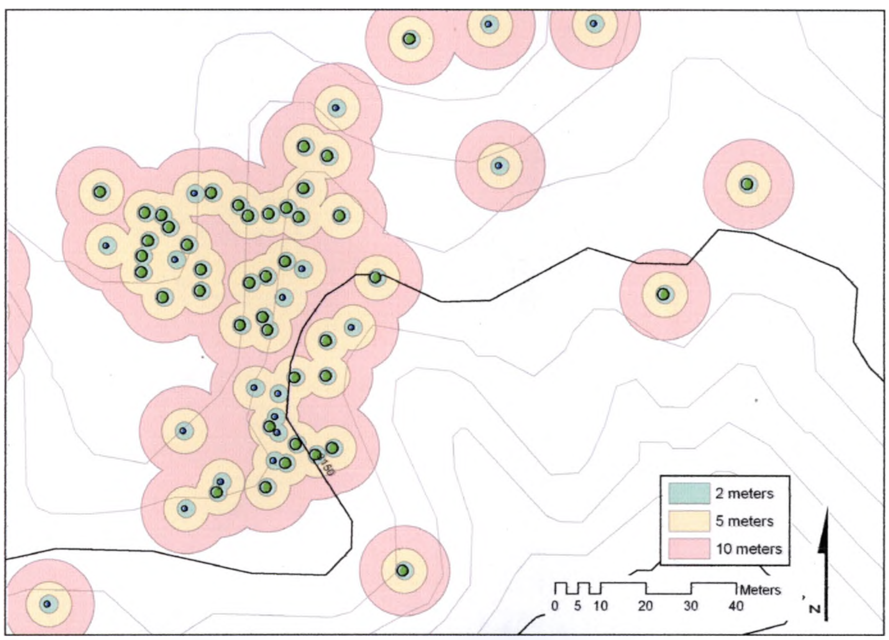


Figure 6-21. Cluster Area 3, sub-cluster 3A, showing small pit classes and their buffer zones. Blue and green dots represent small pit classes.

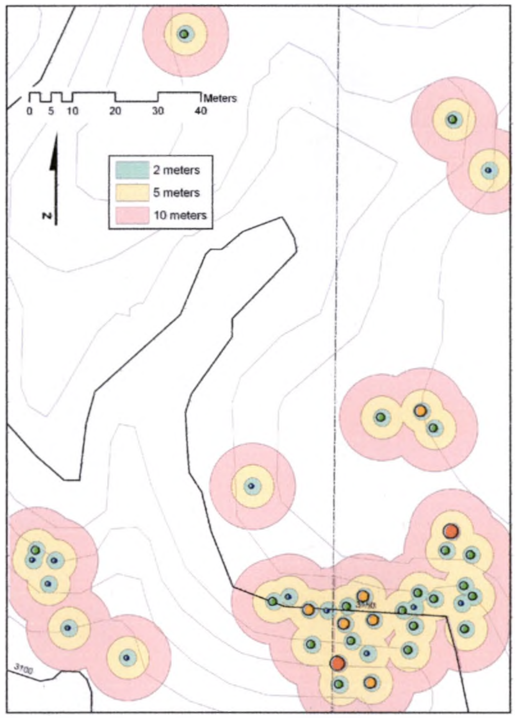


Figure 6-22 Cluster Area 3, sub-cluster 3B, showing all pit classes and their buffer zones.
Red and orange dots represent large pit classes.

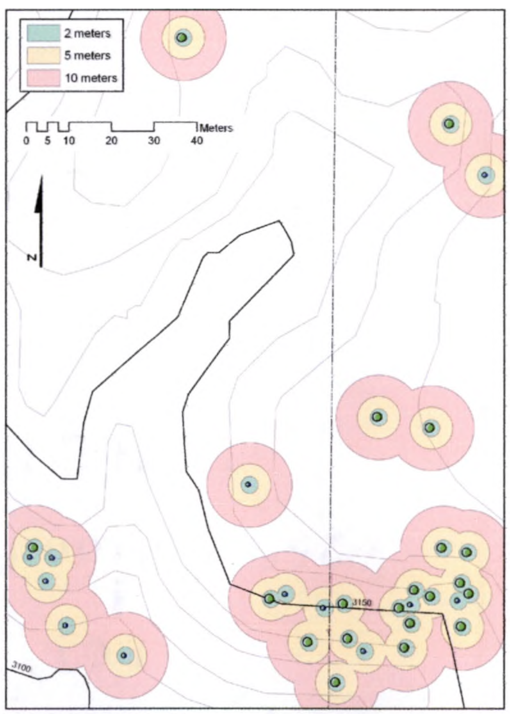


Figure 6-23 Cluster Area 3, sub-cluster 3B, showing small pit classes and their buffer zones.

Cluster Area 4

Cluster Area 4 (Figure 6-24) contains 34 quarry pits. With a *p*-value of 0.20, the highest recorded in this project, there is some room to doubt the results of the orientation of this Cluster Area. There may be a mixing of mapping data points within this Cluster Area. The nearest neighbor ratio of 0.88 indicates (Table 6-12), that though somewhat clustered, the clustering trends toward random dispersion. Twenty-eight of the 34 reported pits in the Cluster Area are small class pits, 50% of them are in Class 2, the larger class of small pits (Table 6-12). Only three of the six reported large class pits are within 10 meter buffer zones.

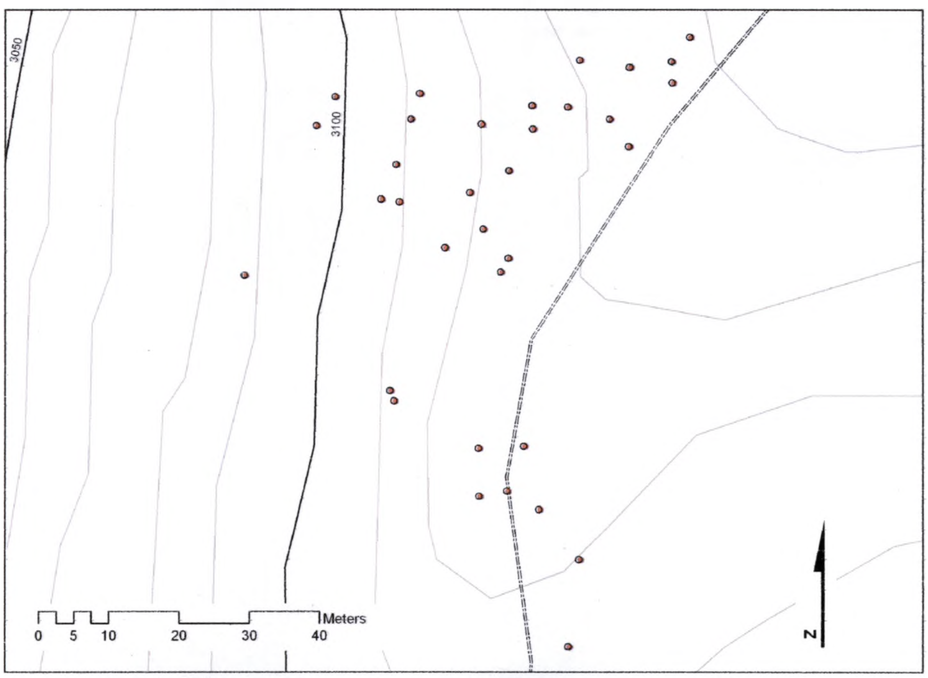
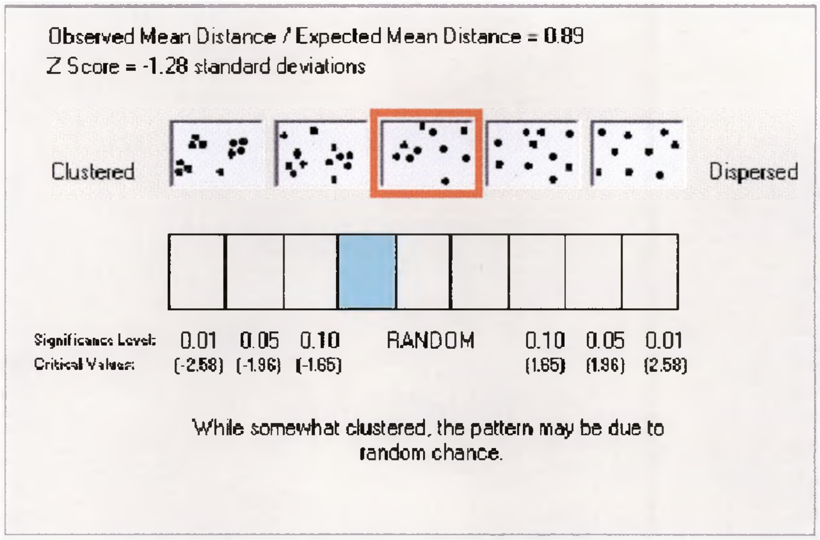


Figure 6-24. Cluster Area 4 quarry pits.

Table 6-12. Average nearest neighbor analysis for Cluster Area 4.



Average Nearest Neighbor Summary
Pit Count: 34
Observed Mean Distance: 5.343793 **Expected Mean Distance:** 6.034880
Nearest Neighbor Ratio: 0.885485 **p-value:** 0.201453

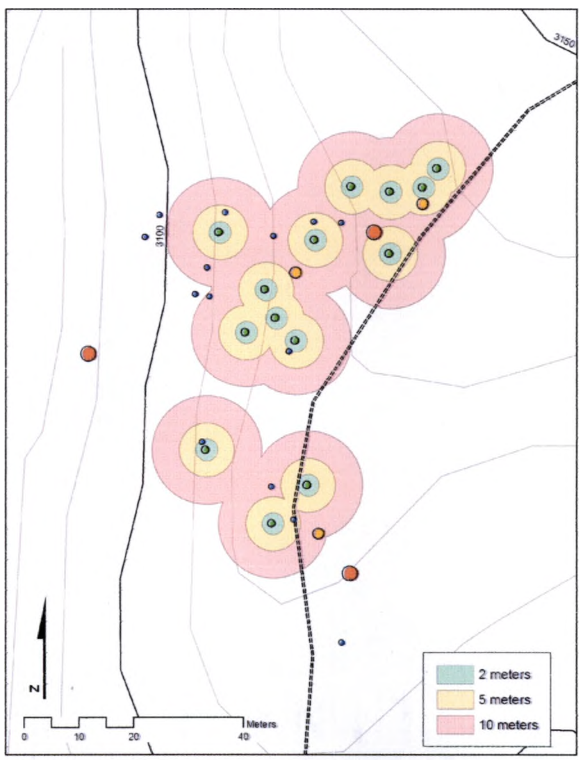


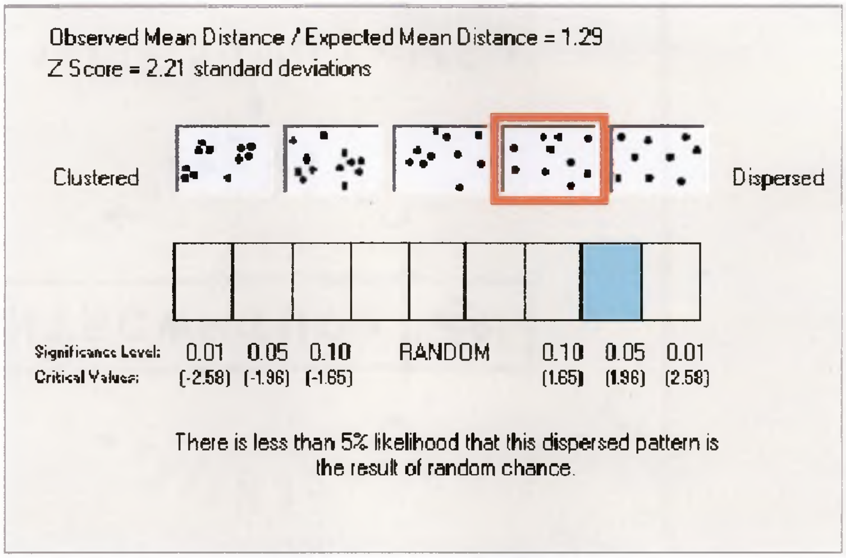
Figure 6-25. Cluster Area 4, showing all pit size classes and their buffer zones.
Red and orange dots indicate large class pits.

Cluster Area 5 and Ground Truthing of Data

Cluster Area 5 is a small area with 16 recorded quarry pits (Figure 6-26). The Cluster Area ranges over nearly 150 meters and allowed for a clear means to document the survey errors noted throughout this document. Statistics for this Cluster Area showed it to be more dispersed than clustered (Table 6-13). The nearest neighbor ratio was 1.3, indicating that the observed mean distance between pits was greater than expected. The relatively low p-value of 0.02 indicates a moderately high level of data confidence.

Figure 6-26. Cluster Area 5, showing all 16 pits.

Table 6-13. Average nearest neighbor analysis for Cluster Area 5.



Average Nearest Neighbor Summary
Pit Count: 16
Observed Mean Distance: 17.891250 **Expected Mean Distance:** 13.885995
Nearest Neighbor Ratio: 1.288438 **p-value:** 0.027299

Cluster Area 5 proved to be very interesting in nature. All of the verified quarry pit locations were offset a consistent 50 meters from the locations denoted by Katz and Katz (1999b) (Figure 6-27). This reflects upon the error invoked by the use of GPS during the time when Selective Availability (SA) was in effect. As noted elsewhere in this thesis, the erroneous time information reported by SA can cause this kind of offset of plotted points away from their actual locations. In addition, the *angle* of the offset showed no consistency, reflecting additional errors caused by the use of different backsights for mapping data points. Here we see that because of the multiple angles of offset, that Cluster Area 5 is composed of points plotted with different mapping stations as references. Approximately 25 meters from the nearest cluster the ground truthing team found a feature, a work area comprising a scatter of Alibates chert flakes approximately 10 meters in diameter (Figure 6-28). Also found was a biface tool made of Alibates chert

(Figures 6-28 and 6—29) that shows evidence of repeated re-sharpening on its bit end (Figure 6-30). This tool is significant, because up until its discovery, there have been no reported finds of any stone tools at the Alibates Quarries. The tool was left where found and no other examination performed upon it. These discoveries, along with the quarry pits, coupled with an absence of pits at the Katz team's reported locations, would seem to validate those data collected during the ground truthing.

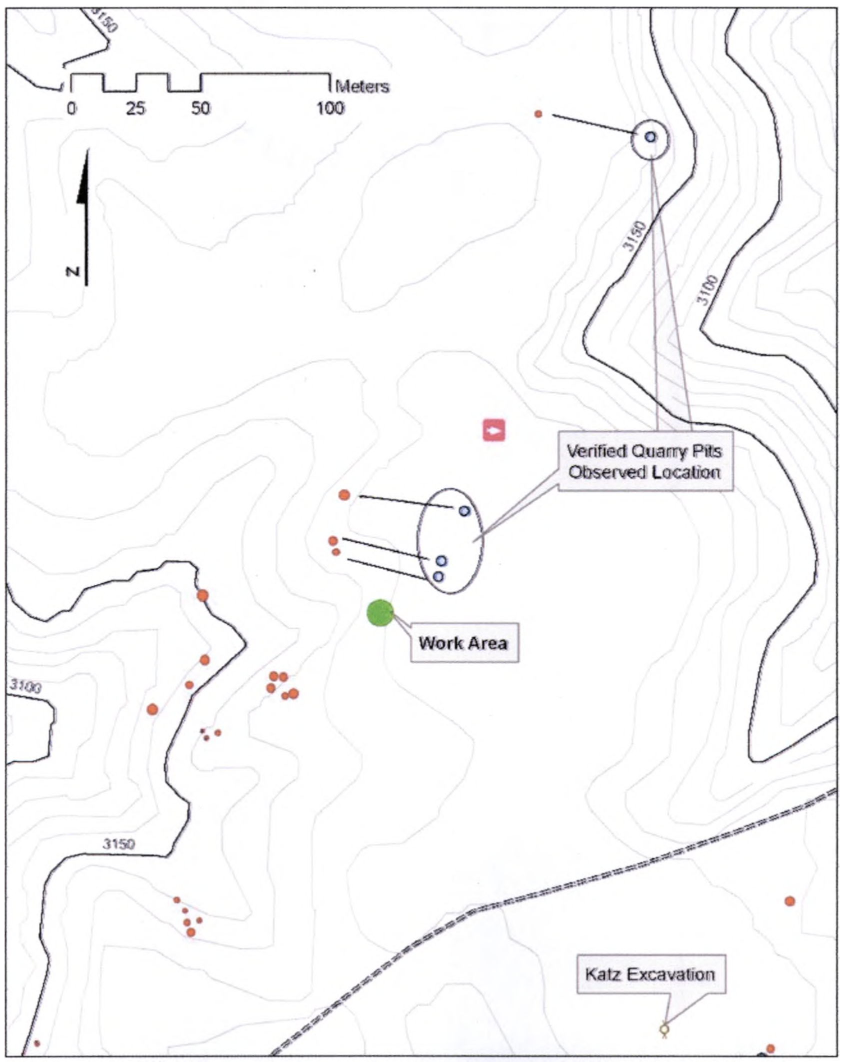


Figure 6-27. Cluster Area 5, showing actual and verified locations of quarry pits and site of Katz and Katz 1993 excavation.

Figure 6-28. Close up of lithic debitage observed at suspected work area in Cluster Area 5 (Photo: Charles Swenson).

Figure 6-29. Close up of bifacial flint tool found at Cluster Area 5 (Photo: Charles Swenson).

Figure 6-30. Close up obverse view of bifacial tool seen in Figure 6-29 (Photo: Charles Swenson).

Figure 6-31. Close up of bifacial tool shown in Figures 6-29 and 6-30. Note flake scars from repeated re-sharpening at the bit edge (Photo: Charles Swenson).

CHAPTER VII

CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

This thesis represents the first attempt to describe and interpret quarry pit distributions at Alibates Quarries. The intent was to investigate whether patterning could be inferred from the unpublished results of a survey conducted at Alibates Quarries in 1999 by Susana and Paul Katz. In addition to statistically determining the degree of possible cluster patterning in the pit alignments, an attempt was made to determine if there were any interrelationships within clusters by examining the buffer distances between quarry pits.

Nearest neighbor analysis performed on the Alibates Quarry pit locational data showed a definite trend toward patterned clustering of the pits as opposed to either random clustering or an even distribution. The computed nearest neighbor ratios indicate that the tendency toward patterned clustering increases as the sample size (number of pits per Cluster Area) is increased (Table 7-1). It is possible that errors in samples are "diluted" somewhat when they are sampled *en masse* and that patterns associated with them are reported with more confidence. A closer look at the reported statistics for the data set informs us of the extent of the Katz and Katz survey team data collection errors.

Levels of confidence in the data set used for the study were expressed as *p*-values, and ranged from 0.0 to 0.28. This range of confidence levels, in part, may be an indication of the errors in the survey strategy implemented by the Katz and Katz (1999a, 1999b) field team, but more detailed ground truthing and mapping would be needed to say this with any confidence. As seen in Figure 6-27, ground truthing these data indicated that the reported three dimensional locational data suffers from inaccurate plotting of mapping stations and unverifiable backsight angles. As two dimensional data, only those data reflecting the location of pits mapped from a single mapping data station are reliable. The higher *p*-values associated with data from for Cluster Areas such as 4 (0.201), 5(0.027) and sub-cluster 2C (0.287) likely reflect an inclusion of data points collected from more than one mapping station. In fact the same pattern emerges for *p*-values as for nearest neighbor ratios, namely that as the number of pits in a sample (Cluster Area, or sub-cluster) decreases, there is less confidence in trends interpreted from those data (Table 7.1) (Figure 7.1).

Table 7-1. Spatial Data Summary for researched quarry pits at Alibates Quarries.

Cluster Area	Nearest neighbor ratio	Observed patterning	*P*-value	# of sampled pits
ALL PITS	0.32	Yes	0.000000	729
1	0.66	Yes	0.000000	254
2	0.56	Yes	0.000000	187
2A	0.79	Yes	0.007516	45
2B	0.78	Yes	0.000097	87
2C	1.09	Random	0.287464	33

Table 7-1.-Continued.				
Cluster Area	Nearest neighbor ratio	Observed patterning	*P*-value	# of sampled pits
2D	0.80	Moderate	0.077945	22
3	0.76	Yes	0.000001	128
3A	0.86	Moderate	0.017754	87
3B	0.80	Moderate	0.015460	41
4	0.88	Random	0.201453	34
5	1.28	Moderate dispersion	0.027299	16

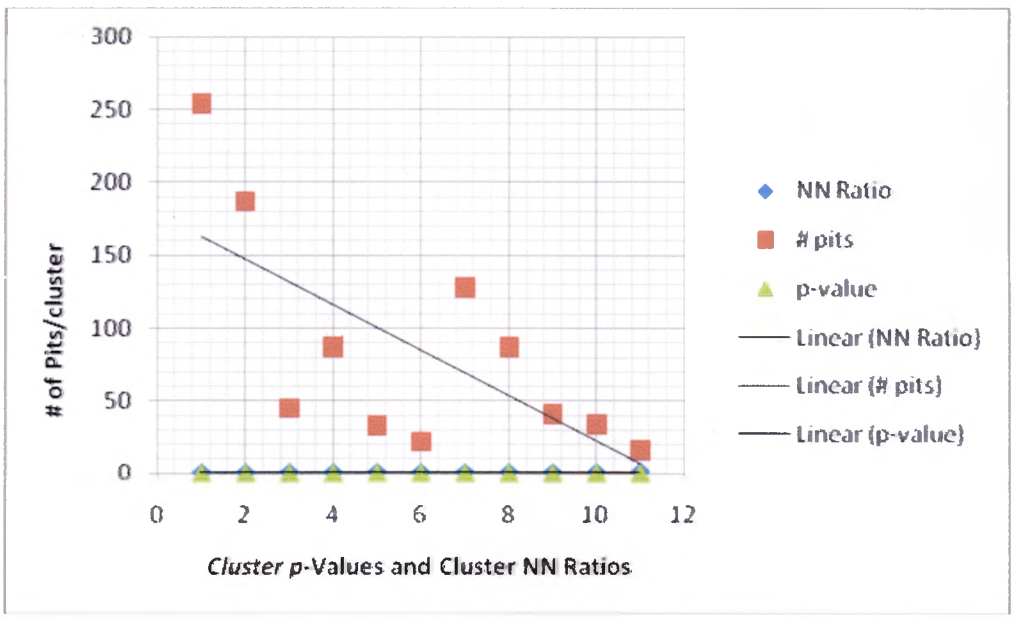


Figure 7-1. Simple scatter plot of computed statistics for all Cluster Areas. Plot illustrates trend of decreasing computed NN ratio (nearest neighbor ratio) and *p*-values for Cluster Areas as the number of pits per Cluster Area increases.

An examination of pit buffering in Cluster Areas showed that pits within clusters and/or sub-clusters, in the two smallest surface area classes, were consistently (over 99%

of the time) located at five or ten meter distances from each other, and rarely (less than one percent of the time) at greater distances from each other. It should also be noted that in all but one case (Cluster 4), pits of the two largest surface area classes seem to intrude, or impinge upon the pits of the smaller classes and/or the smaller pits' buffer zones. This could indicate some form of chronology, with either the bigger pits being dug first, or vice versa, nonetheless implying a shift in the way mining was organized. Statistical examination of pit patterning shows that the null hypothesis is falsified and that there is patterning in the quarry pits at Alibates Quarries. This thesis' hypotheses are encapsulated within the three models presented in Chapter IV: the *Overseer* and *Competing Groups Models* have at their core the hypothesis that there is a patterning to pit orientations; the null hypothesis being represented by the *Random Model*. In addition to falsifying the null hypothesis, the data also falsifies the Overseer Model as no pit orientations represented an even distribution of quarry pits. Pit patterning at Alibates Quarries seems to adhere most closely to the proposed Competing Groups Model (Figure 4.2). However, as noted earlier, until further research is performed at the quarries, the problem of the equifinality of other possible explanations cannot be ruled out—for example, the smaller pits could have been used for prospecting for chert seams rather than being used for the main acquisition of chert. Presumably, the smallest pits dug might have been similar to a test excavation; a shallow, narrow pit might expose shallow deposits of chert, generating a reason for digging a larger pit for major excavation purposes. But the smallest pits could as easily have been small fire pits used to keep the miners warm during cold weather—there is no indication whether or not mining was a seasonal pursuit. Only further field work will provide data that could illustrate the pits true functional relationships.

The discovery of a bifacially-flaked chert tool during ground truthing is also significant (Figures 6-29, 6-30, 6-31). It is the first reported tool found at Alibates Quarries. The presence of re-touching at the blade end indicates its use in the mining process. In morphology it is similar in shape tools to mining tools found at other mines—one example, is a tool possibly recovered by Holmes in 1903 from the Leslie Mine (23FR115) in Missouri (Figure 7.2) (Fuller 2007). In a PowerPoint presentation given by Paul Katz in 2008, he posited that the miners at Alibates Quarries used tools designed to pry out tabular blocks of chert. The tool observed at Alibates Quarry has a wide blade that would work for prying, the force required for such prying would necessitate frequent re-sharpening of the blade end. Use wear analysis of this observed tool might reveal polish or striations that would confirm its function. During an examination of the lithic assemblage recovered from the Baker and Baker excavations at Alibates Ruin Number 28, the author of this thesis observed over one hundred lithic tools that share some similarities to the tool seen at the Alibates Quarries. One such example can be seen in Figure 7-3, and while not exhibiting the same flaking pattern as the in-situ example, has a similar morphology, and could represent a pre-form of this tool.

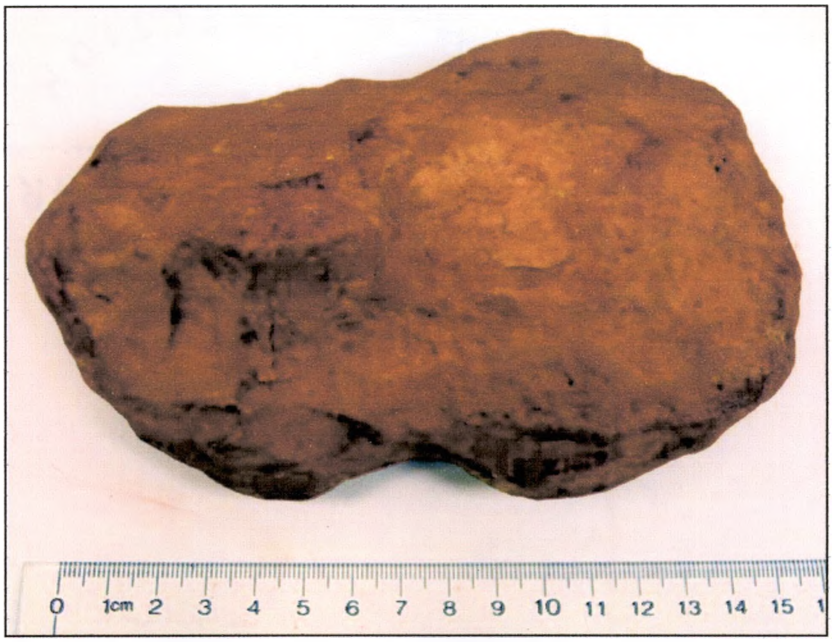


Figure 7-2. Tool described as "grooved, iron stained nodule" used in mining of hematite at Leslie Mine, (23FR115), Missouri (Fuller 2007).

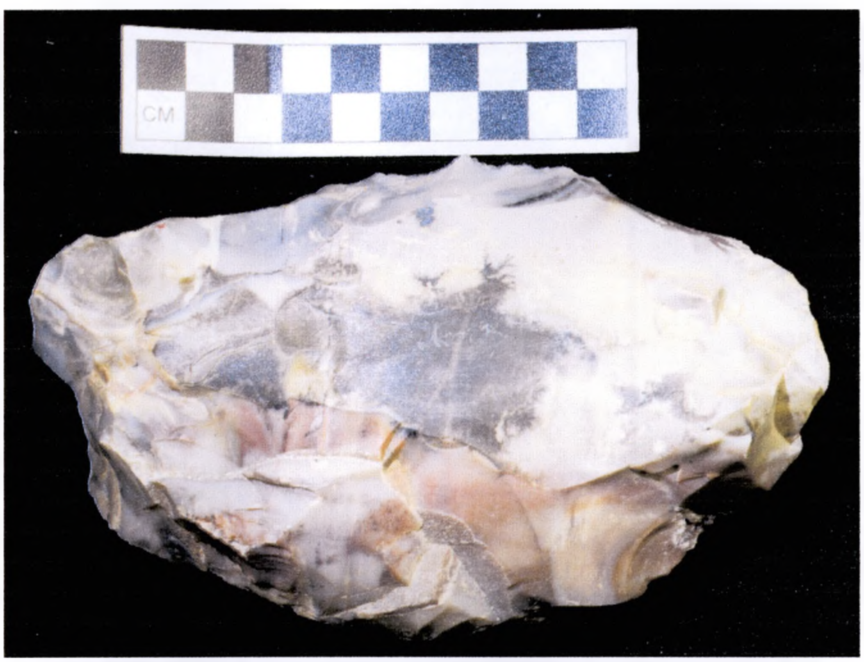


Figure 7-3. Bifacial tool recovered at Alibates Ruin Number 28 by Baker and Baker (2000) (Photo: Chris R.L. Davis, 2009).

Future Research Directions

It is hoped that this thesis will open up a new area of investigation for research at Alibates Quarries through the use of GPS technology and additional investigations of the quarry pits. In order to truly test the results of this thesis it will be necessary correct the errors noted in these Katz and Katz (1999a, 1999b, 2003) survey data. It is possible that the defined relationships could be ground truthed with high resolution GPS readings taken on multiple pits for each mapping station, but a full re-survey would be preferred. In addition, a pedestrian survey of the pit areas would reveal the presence of more areas containing lithic scatters of small flaked materials, and therefore enable the mapping of possible reduction areas. This would further articulate the mining process in more detail. A test excavation of large surface class pits in Cluster 4 could reveal something about the implied sequence of pits noted above. It is doubtful that any organic materials would be recovered from such excavations, but the order in which the pits were dug could be inferred by determining the order of pit overlap and stratigraphic relationships through study of the excavated stratigraphic sequence.

The use of GIS products, such as Arc-GIS software coupled with high resolution GPS hardware will allow for a new means to investigate the relationship of the hundreds of occupational sites that surround the Alibates Quarries. If indeed, the work performed at the quarries was organized by some form of group, where were these people based? Could there be a relationship between Alibates Ruin Number 28 and Alibates Quarries, or was some other nearby occupation at the center of these activities? A project involving the addition of the entire region's sites to a GIS database, complete with descriptive information, would allow for the discovery of more spatial correlates to be used for similar analyses as presented in this thesis.

A complete inventory and use-wear study of tools found at various sites could also be informative and aid in the investigation of who mined the chert at Alibates Quarry, and how they were organized. Chris Lintz is presently analyzing more than 1000 photographs of over 300 lithic tools recovered at Alibates Ruin Number 28 that are similar in morphology to the tool found at Alibates Quarries (personal communication, 2010). These recovered tools exhibit variability in morphology that hint of being at different stages of manufacture of some yet unidentified finished tool. They have also not yet been subject to use-wear analysis. If the tools prove to be indeed similar in typology to the tool observed at Alibates Quarries, then there is a stronger inference that the occupants of the Ruin were associated with mining at the Quarries. Furthermore, if an investigation of lithic assemblages from other sites proves to contain similar tools in similar numbers, also representing different stages of manufacture, it would be reasonable to also associate them with the mining at Alibates Quarries. The absence of such tools would imply the opposite influence on mining operations—much more research is needed to form solid conclusions.

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