

**A GIS BASED APPROACH TO THE SPATIAL ANALYSIS OF THE
FINCASTLE BISON KILL SITE (DIO_x-5)**

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Abstract

The Fincastle Bison Kill Site (D1Ox-5), located in Southern Alberta, Canada, yielded a significant number of archaeological remains, including projectile points, lithic tools, debitage, fire broken rock (FBR) and fauna. The large 81 m² East Block excavation area provided an opportunity to spatially analyze the remains from this part of the site using a Geographic Information System (GIS), a program that is becoming more widely employed and accepted in archaeology. This research explored the benefits of using a GIS to spatially analyze archaeological sites by using the data collected from the excavations carried out at the Fincastle Site. The process of applying spatial statistical tests and creating distribution maps within the GIS software was outlined, and the results were archaeologically interpreted. It was confirmed that a GIS can perform all of the tasks needed to spatially analyze an archaeological site and the additional benefits make a valuable component of archaeological research.

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Chapter 1 – Introduction

Introduction

The Fincastle Bison Kill Site (DIOx-5), located approximately 100 km east of Lethbridge, in Southern Alberta (see Figure 3.1), yielded a number of archaeological remains. In order to assess the site before it was destroyed by looting, excavations led by Dr. Shawn Bubel of the University of Lethbridge took place in 2004, 2006 and 2007. The projectile points and significant number of faunal remains suggested hunting and butchering activities took place there 2,500 years ago. Though research on the site is still ongoing, three graduate students have completed their thesis research on the site involving the use of Geographic Information System (GIS) applications in archaeology (Lieff 2006); a comparative study of the lithic artefacts (Varsakis 2006); and the analysis of butchering activities (Watts 2008). This research serves to add to the understanding of the site by building on the previous research and providing an innovative way to analyze the remains, that being a spatial analysis of the site using a Geographic Information System.

Although this thesis does not explore the temporal aspect of the site, it is important to place Fincastle in a cultural context. The prehistory of the Alberta Plains region is separated into three cultural periods, each represented by diagnostic projectile points. According to Vickers' (1986) overview, the Early Prehistoric (11,500 – 7,500 BP) is characterised by the presence of large, lanceolate points that were likely hafted to large wooden spear shafts. The Middle Prehistoric (7,500 – 1,750/1,250 BP) is divided into three sub-periods and is characterised by medium sized projectile points that were hafted to smaller dart shafts that were thrown with atlatls (throwing spears). The last phase is the

Late Prehistoric (1,750/1,250 – 250 BP), which reflects the appearance of small projectile points that were used with the bow and arrow.

The Middle Prehistoric is a relatively well-known temporal period. It is separated into three sub-periods: the Early Middle Prehistoric I (7,500 – 5,000 BP), the Early Middle Prehistoric II (5 000 – 3 500 BP) and the Late Middle Prehistoric (3,500 – 1,750/1,250 BP) (Vickers 1986: 12). Just under two thirds of the excavations in this region fall within in this period and about half of these are Late Middle Prehistoric sites (Vickers 1986: 54). Most of the sites relate to bison hunting and processing, as is the case for the Fincastle Site. The five radiocarbon samples from the bone bed date the site to 2,500 years ago, which places it within the Late Middle Prehistoric Period.

In the Late Middle Prehistoric Period there are a number of different cultural groups, the two dominant being Pelican Lake and Besant (Vickers 1986: 74). Large-scale bison hunting occurred during this period, with the majority of the sites reflecting killing in pounds or jumps, though animal processing and camping sites are also numerous.

Research Objectives

In order to fully understand an archaeological site, all remains recovered must be studied individually, in conjunction with one another, and within a site, regional, cultural and chronological context. The spatial analyses of an archaeological site examine the relationships between the remains, which can assist in the cultural interpretation. The main research objective of this thesis was to analyze the spatial patterns of the archaeological remains from the East Block of the site using a Geographic Information System (GIS).

A GIS is a very strong analytical tool that can visually display spatial relationships that may not be obvious when looking at field maps. Moreover, the software includes spatial statistical tests that can be used to examine the distribution of the archaeological remains. This makes it an ideal program for archaeologists to use because it can do it all, from creating visual display maps to calculating the spatial statistics.

In order to use a GIS to study the spatial relationships, detailed spatial information must be collected in the field during the excavations. These data were available for this thesis research as was the attribute information associated with the archaeological remains. These data were entered into Access databases, which were easily imported into the GIS. This served as the starting point of this thesis research.

Thesis Overview

This thesis is organized into five chapters. Reviewing the available literature on the use of spatial statistics in an archaeological setting was needed because particular tests are traditionally used to examine the cultural remains found at a site. It was also important to review the use of GIS in the discipline of archaeology. These past studies served as the foundation for this research, upon which the spatial analysis of the Fincastle Site was carried out. The figures were inserted and discussed in the appropriate sections because the analyses of the spatial distribution of the remains were both visually output as well as statistically examined.

Chapter 2 – Spatial Analysis Literature Review

This chapter provides an overview of the different types of spatial statistics used in archaeology. Quadrat analysis and the nearest neighbour method are the most

frequently used spatial statistics in archaeology, but kernel density estimation, Moran's I, Getis-Ord General G_i^* , Ripley's K and K-means statistical methods have also been used. These statistics are described in detail, including how they were applied to archaeological projects.

The second part of this chapter discusses the different applications of GIS use in archaeology. Since using a GIS in an archaeological project is a relatively new technique, there were a limited number of published articles reviewed and discussed. Those selected represent the current state of GIS use in archaeology.

Chapter 3 – Fincastle Site Introduction and GIS Methodology

An overview of the Fincastle Site and excavation methodology is provided in Chapter 3. The site description, including the fauna, flora and environment are presented. The field methodology that was used in all three field seasons is described, as well as the stratigraphy and radiocarbon dates. This chapter also includes the laboratory procedure used in the analysis of the archaeological remains. The results obtained from work completed on the lithics, fire broken rock (FBR) and faunal remains is summarized as well.

The second part of this chapter outlines the GIS methodology. It includes an outline of the scanning and registering of the level graphs, the digitization of the remains, the calculation of the centroids, the plotting the UTM coordinates, calculating the spatial statistics and creating the visual outputs for the spatial interpretation.

Chapter 4 – The Spatial Analysis of the Fincastle Bison Kill Site (DIOx-5)

The results from the spatial analyses carried out on the archaeological remains found at the Fincastle Site using a GIS are presented in Chapter 4. Five types of

archaeological remains were included in the spatial analysis: projectile points, lithic tools, debitage, FBR and fauna. Spatial statistical methods (nearest neighbour, Moran's I, Getis-Ord General G_i^* and Ripley's K function) were applied to each type of remain to determine their type of spatial distribution. Quadrat analysis and kernel density estimation were carried out on remains that had enough data to provide a visual output of the calculated distribution.

Distribution maps of selected aspects of each type of archaeological remain were also created. These maps were studied in the hope of understanding of the spatial distribution of the archaeological remains. While some of the remains were interpreted individually, others were observed together to fully explore the relationships between the remains found at the site.

Chapter 5 – Conclusion

This chapter provides a summary of the research carried out in this thesis. The benefits of using a GIS in an archaeological setting are highlighted. Future directions of the use of GIS in the discipline of archaeology are also discussed.

Chapter 2 – Spatial Analysis Literature Review

Introduction

Advanced statistical spatial analysis, as a scientific method, was conceived in the 1950s. Archaeologists adopted it in the 1970s. Binford's (1978a; 1978b) research with the Nunamuit group in Alaska was the first archaeological study of the spatial distribution of artefacts. His research showed the value of performing spatial analysis on archaeological assemblages. The discipline, as a whole, did not implement many of the advanced techniques, such as calculations relating to density across horizontal space or relationships between different archaeological remains in three dimensions (Hodder and Orton 1976; Conolly and Lake 2006: 149). With a renewed interest in spatial analytical techniques, archaeologists are now noting the potential of performing detailed and systematic studies of past human behaviour by examining spatial patterning in archaeological data.

Spatial analysis focuses on the spatial structure of variables to determine the intensity of patterns, thereby obviating them in complex data sets (Hodder and Orton 1976: 2; Ives 1985: 46; Legendre and Fortin 1989; Dale et al. 2002). It employs the use of dot location maps, which are normally created to observe obvious patterns in the data before spatial statistics are applied. These patterns can help detect concentrations of artefacts, features and sites, as well as describe, interpret and explain the spatial relationships that exist (Hodder and Orton 1976: 85; Shennan 1997: 220; Ebert 2004: 321; Conolly and Lake 2006: 162).

The point patterns can also give insight on the boundaries of cultural activities. Kooyman (2006) proposed that social spaces have boundaries and transitions, with some

boundaries being more flexible than others. Certain activities, such as a bison processing location, would have an impermeable boundary (Kooyman 2006: 427). This means that the boundary would be visible and it is likely that no other activity would take place in that area due to the risk of meat contamination. Activities that had a flexible boundary include cooking areas where other cultural activities could have also occurred (Kooyman 2006: 427). Where boundaries overlap, there is an indication that different cultural activities took place at the same time (Kooyman 2006: 434).

Though somewhat apparent, it can be difficult to draw conclusions based on visualization alone (Hodder and Orton 1976: 2; Unwin 1981: 29; Bailey and Gatrell 1995: 81). Therefore, statistical measures are used to evaluate the data and to verify whether patterns truly exist (Ives 1985: 46; Bailey and Gatrell 1995; Conolly and Lake 2006: 149).

Spatial analysis can be carried out on archaeological data to examine the distribution of the archaeological remains in many ways. They can be used to describe and analyze distributions in order to obtain greater precision and reliability (Hodder and Orton 1976: 7). They have also been used to examine the process that leads to the formation of an archaeological pattern, such as diffusion and trade (Hodder and Orton 1976: 8). In general, these techniques are used to determine if the spatial distribution of points have a regular, random or clustered distribution (Hodder and Orton 1976; Ives 1985: 46). As depicted in Figure 2.1, a regular distribution will display a systematic spacing in the observed points, while a random distribution will have unsystematic spacing within the study area (Hodder and Orton 1976: 53-54; Ives 1985: 46). A clustered distribution will exhibit aggregations in the data (Hodder and Orton 1976: 85;

Ives 1985: 46). Cultural (or natural) formation processes can be inferred using these types of patterns. In most cases, clustering of data indicates cultural activity. However, certain attribute clusters may relate to specific cultural activities, such as bone boiling or tepee construction.

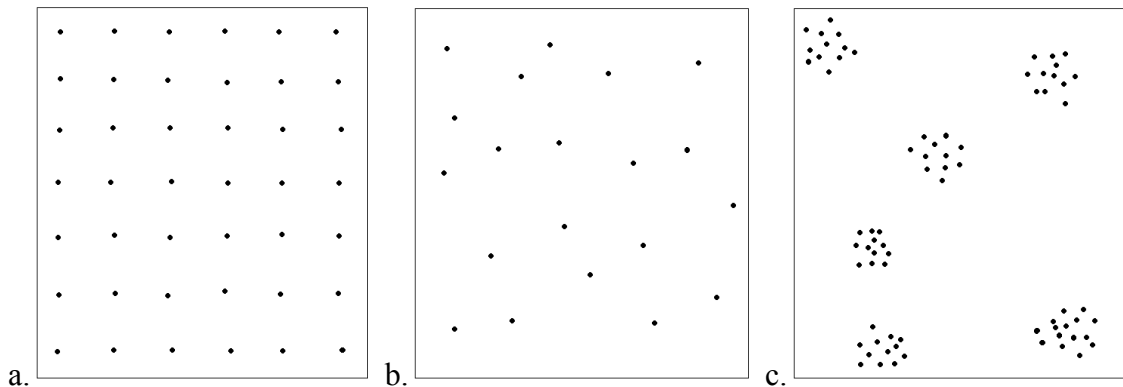


Figure 2.1: Types of spatial distributions: regular (a), random (b) and clustered (c).

The most frequently used statistical methods used to spatially examine clustering at an archaeological site are “Quadrat analysis”, the “nearest neighbour” and “K-means”, but other techniques such as the “kernel density estimation”, “Ripley’s K function”, “Moran’s I” and “Getis-Ord General G_i^* ” tests can also be useful.

Statistical Techniques

Quadrat Analysis

Quadrat, or density, analysis is a frequently used spatial technique to interpret the distribution of archaeological remains. The site under evaluation is partitioned into sub-regions of equal areas, usually squares, called quadrats (Hodder and Orton 1976: 33; Cliff and Ord 1981: 87; Ripley 1981: 102; Unwin 1981: 38; Bailey and Gatrell 1995: 84;

Rogerson 2006: 224-225). Each point that falls into a quadrat is counted and the sum is recorded (e.g., Figure 2.2).

5	8	17	12	1	6
11	10	3	15	7	4
13	1	4	2	13	9

Figure 2.2: An example showing the basic concept of quadrat analysis.

The quadrat sums are then compared, and areas of intensity and changes over the region of study are noted (Hodder and Orton 1976: 33; Cliff and Ord 1981: 87; Ripley 1981: 102; Unwin 1981: 38; Bailey and Gatrell 1995: 84; Rogerson 2006: 224-225). The data are considered clustered if there is significant variability in the number of points from quadrat to quadrat (i.e., there are more points in some areas compared to others), while little variability demonstrates regularity (Hodder and Orton 1976; Unwin 1981: 39; Rogerson 2006: 225).

If quadrat sizes are made smaller in order to gain a higher spatial resolution, increased variability in quadrat counts can occur. This will eventually degenerate into a distribution with many empty quadrats, making meaningful interpretation impossible (Hodder and Orton 1976: 36; Cliff and Ord 1981: 92; Ripley 1981: 106; Bailey and Gatrell 1995: 84; Rogerson 2006: 225). A similar situation can occur if the quadrat size is too big, which results in missed patterns in the data (Hodder and Orton 1976: 36; Cliff and Ord 1981: 92; Ripley 1981: 106; Bailey and Gatrell 1995: 84; Rogerson 2006: 225). Therefore, the size of the quadrats must be carefully chosen to reflect the type of archaeological problem being investigated. This requirement means that the method is not free of statistical bias. Another weakness of quadrat analysis is that much of the

spatial data, such as distance, is lost because it only examines the number of points within a quadrat (Hodder and Orton 1976: 36; Cliff and Ord 1981: 92; Ripley 1981: 106; Bailey and Gatrell 1995: 84; Rogerson 2006: 225).

These shortcomings aside, quadrat analysis is one of the most common techniques used to spatially analyze archaeological data because it is one of the simplest ways to summarize point data with an x and y location. For example, Kroll and Isaac (1984) used quadrat analysis to calculate densities of stone tools and bone at Koobi Fora in Kenya. Their findings suggested that stone knapping (flaking) and animal processing occurred in the same area of the site because together they displayed a clustered distribution. Johnson (1984) used a similar technique at Pincevent in France, where distribution maps for lithic (stone) and faunal remains were plotted (outputted) separately. Although these maps were separate, they clearly displayed overlapping areas of use, which also suggested that certain activities were carried out in the same area, a flexible boundary as defined by Kooyman. This technique was also used by Hivernel and Hodder (1984) in Ngenyn in Kenya, by Ferring (1984) in Delaware Canyon, Oklahoma, by Cowgill et al. (1984) in Teotihuacan, Mexico and by Whallon (1973) in Oaxaca, Mexico. De Bie and Caspar (2000) also used quadrat analysis to understand lithic reduction strategies and other cultural activities at the site of Rekem in Belgium.

Since quadrat analysis has limitations, it should not be used on its own to describe the distribution of archaeological remains. More sensitive tests that incorporate distance must be used in conjunction with this method, such as “kernel density estimation” (Bailey and Gatrell 1995: 84) and the “nearest neighbour” statistic (Hodder and Orton 1976; Unwin, 1981 39; Rogerson 2006: 225).

Kernel Density Estimation

Kernel density estimation (KDE) was created to output a smooth distribution map compared to the rougher map that quadrat analysis produces. This is done by extrapolating the distribution of observed data points. The two-dimensional probability density function, the kernel, is placed over these observed points (Bailey and Gatrell 1995: 84; Shennan 1997: 29; Baxter 2003: 29; Conolly and Lake 2006: 175). The relationships between the data points can then be determined and clustered, random or regular spacing noted.

Kernel density estimation is calculated as

$$\hat{f}(x) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{(x-x_i)}{h}\right),$$

where x is the location of the event, K is the kernel function, h is the bandwidth and n is the sample size (Silverman 1986: 15; Bailey and Gatrell 1995: 85; Baxter et al. 1997: 348; Baxter 2003: 30). In this case, K is defined as the quartic kernel and is written as

$$K(x) = 3\pi^{-1}(1 - x^T x)^2 \text{ if } x^T x < 1,$$

where T relates to the area around the point used to calculate the distance. If these conditions are not met, then $K(x)$ is equal to zero (Silverman 1986: 76; Bailey and Gatrell 1995: 85).

Like quadrat analysis, the results depend on the size of kernel used in the interpretation of the distribution. By manipulating its shape and radius, also referred to as the bandwidth, the ideal fit can be calculated (Bailey and Gatrell 1995: 87; Baxter et al. 1997: 348; Shennan 1997: 29; Baxter 2003: 31; Conolly and Lake 2006: 175). Using too wide a bandwidth can result in a distribution that is overly smooth; while too narrow a

bandwidth can produce a rough result where the output may not reflect the actual distribution of archaeological remains (Baxter et al. 1997: 348; Shennan 1997: 30; Baxter 2003: 31; Conolly and Lake 2006: 177). It is important to experiment with the bandwidth value in order to see the different degrees of smoothing in the distribution (Bailey and Gattrell 1995: 87; Baxter et al. 1997: 348; Shennan 1997: 29; Baxter 2003: 31; Conolly and Lake 2006: 175).

KDE has been used in archaeology, but on a much more limited scale than quadrat analysis. Beardah and Baxter (1996) have been largely responsible for the introduction of KDE to the discipline of archaeology, and together with Wright (Baxter et al. 1997) they have published a few cases where they applied this method. Using Binford's (1978a) Mask Site data, they looked at a subset of bone splinter records to support the known locations of hearth activity. Binford had identified five hearth areas at the Mask Site and three areas of dense bone splinters. By using KDE, Baxter et al. (1997: 351) determined that all of the hearths were associated with one or more of the bone splinter concentrations.

Baxter (2003) also used KDE to examine Middle Bronze Age cups belonging to the Apennine culture that occupied the central and southern peninsula of Italy. Data from a subset of 60 cups, including the rim diameter, neck height and total height of the cup (Lukesh and Howe 1978), were taken into consideration when performing KDE. From his investigation it was clear that there were two different styles of cups and he showed that KDE can be useful for comparative purposes as well (Baxter 2003: 35).

Nearest Neighbour Analysis

The nearest neighbour statistical method (Clark and Evans 1954) is another common way to spatially examine archaeological remains. This technique compares the observed average distance (R_o) between points and their nearest neighbour with the distance that is expected (R_e) between neighbours in a random pattern (Clark and Evans 1954: 447; Cliff and Ord 1981: 99; Unwin 1981: 45; Ripley 1988: 23; Bailey and Gatrell 1995: 89; Baxter 2003: 164; Conolly and Lake 2006: 165; Rogerson 2006: 228).

The observed average distance is given by

$$R_o = \sum_{i=1}^n d_i / n,$$

where n is the number of points in the study area and d_i is the distance from point i to its nearest neighbour. The expected average distance is calculated as

$$R_e = \frac{1}{(2\sqrt{\lambda})},$$

where λ is the density of points within the study area. Therefore, the nearest neighbour ratio would be calculated as

$$R = \frac{R_o}{R_e}.$$

If the ratio (R) is less than one, then the distribution is considered clustered, if $R=1$ there is a random distribution and if $R>1$ there is a regular (uniform) distribution (Clark and Evans 1954; Bailey and Gatrell 1995: 89; Conolly and Lake 2006: 164). If there is a perfectly uniform distribution, the ratio of the observed distance to the expected can reach 2.14, but this only occurs in extreme cases (Clark and Evans 1954: 447;

Hodder and Orton 1976: 40; Baxter 2003: 164; Conolly and Lake 2006: 165; Rogerson 2006: 229).

The significance of R is dependent on the sample size and density of the point distribution, therefore, one can determine if R_o differs from R_e by testing the variance.

The variance of mean distances between neighbours is calculated as

$$V[R_e] = \frac{4 - \pi}{4 * \pi * \lambda * n},$$

where n is equal to the number of points within the study area and λ is the mean intensity of points (Baxter 2003: 164; Conolly and Lake 2006: 165; Rogerson 2006: 229). Since the variance is estimated, a z-test can be used to test the null hypothesis of a distribution (Baxter 2003: 164; Conolly and Lake 2006: 165; Rogerson 2006: 229). The null hypothesis is defined as a state of no significance, or that there is no difference between the distribution being tested from a random distribution (Conolly and Lake 2006: 123; Rogerson 2006: 98). If the null hypothesis is rejected, then the distribution is considered non-random. The z-test is calculated as

$$z = \frac{(R_o - R_e)}{\sqrt{V[R_e]}}.$$

The z values from this calculation are found on the Table of Standard Normal Distribution and can be used to indicate the significance of the distribution (Conolly and Lake 2006: 165; Rogerson 2006: 229). If the value of z is 1.96 or higher it indicates that there is a significantly uniform distribution. Values of -1.96 or lower indicate a trend towards clustering in the distribution (Conolly and Lake 2006: 165; Rogerson 2006: 229). Therefore, if the value falls between 1.96 and -1.96, there is a random distribution. These values are based on a 95% confidence level.

While the nearest neighbour statistic takes into consideration the distance between points, there are several limitations in this method. Study areas that are long and narrow can naturally output a clustered distribution because the points are limited to one axis and thus seem closer to each other (Clark and Evans 1954: 449; Hodder and Orton 1976: 41; Ripley 1981: 153; Unwin 1981: 46; Bailey and Gatrell 1995: 90; Baxter 2003: 164; Conolly and Lake 2006: 165-166; Rogerson 2006: 229). A defined study area may create a boundary that can affect the ratio because a point's expected nearest neighbour may fall outside the study region. Setting a buffer zone just outside the study area can help rectify this situation. By including space directly outside the study area, a point's expected nearest neighbour can be taken into consideration and the statistical output will be more realistic (Clark and Evans 1954: 449; Hodder and Orton 1976: 41; Ripley 1981: 153; Unwin 1981: 46; Bailey and Gatrell 1995: 90; Baxter 2003: 164; Conolly and Lake 2006: 165-166; Rogerson 2006: 229).

Moreover, the nearest neighbour statistical method only takes into account the first neighbour, no matter the direction in which it lies. Therefore, if clustering is evident, it is only recognized on a small spatial scale (Clark and Evans 1954: 450; Hodder and Orton 1976: 41; Unwin 1981: 46; Bailey and Gatrell 1995: 89; Conolly and Lake 2006: 164; Rogerson 2006: 229). Statistics that look beyond the first neighbour, to the second or higher neighbours, can help alleviate this problem.

Nearest neighbour calculations have been used to detect the regional clustering or segregation of archaeological sites on the landscape. Hill's (2000) study looked at the segregation of settlements in the Wadi al Hasa of west-central Jordan. Using the nearest neighbour statistical method, he determined that the settlements were not clustered in the

area, over different time periods (Hill 2000: 232). This result fit with the interpretation that the sites were quickly abandoned and set up elsewhere in the area because the Wadi al Hasa region contains easily degraded soils that cannot support long enduring occupations of agricultural communities (Hill 2000: 232).

The nearest neighbour statistical method can also be used to determine the spatial patterning of archaeological remains within a single site. For example, nearest neighbour analysis was used to study the artefact distribution at HkPa-4, a boreal forest site located in northern Alberta (Ives 1985). Ives (1985: 54) went further than the nearest neighbour and applied a second neighbour and higher function to the formula that is normally not used. Since the study area was small, a limited amount of archaeological data was recovered (Ives 1985). In this case, the results from Ives' nearest neighbour calculations were not strong enough to show cultural activity concentration zones, although he suggested that clustering was evident based on the maps of archaeological remains he observed. This is a good example to show that larger study areas with more archaeological remains are needed to produce quantifiably valid results.

This was the case for Whallon's 1974 study on stone tool types scattered over a Proto-Magdalenian occupation floor at the Abri Pataud rock shelter in southwestern France. The occupation was excavated over an area that was 12 m long and 2-3 m wide (Whallon 1974: 24). Four stone tool types were chosen for the study because they showed the strongest spatial patterning. Whallon (1974: 31) showed that all four distributions were significantly clustered and therefore, demonstrated the usefulness of the nearest neighbour method.

Ripley's K Function

The Ripley's K function was designed to identify the relative aggregation or segregation of point data at different spatial scales (Ripley 1977, 1981, 1988). This method gets past the problems in the nearest neighbour method because it takes the relationships beyond the nearest neighbour into account. Moreover, the shape of the study area has little effect on the results because this method corrects for the boundary, or edge effect, in the equation (Bailey and Gatrell 1995: 92; Baxter 2003: 167). The Ripley's K method looks for point intensity in the distribution area by including the expected number of neighbours within a circle of a defined radius and compares that to the observed values (Bailey and Gatrell 1995: 92; Pélissier and Goreaud 2001: 101; Baxter 2003: 166; Conolly and Lake 2006: 166). The actual distribution is, therefore, made up of a cumulative frequency distribution of average point intensity at set intervals of the radius (Bailey and Gatrell 1995; Baxter 2003; Conolly and Lake 2006: 166).

The Ripley's K function can be calculated in two different ways and is defined as $\lambda K(r) = E(\# \text{ of events within a distance } r \text{ from an arbitrary point})$, where λ is the mean number of events per area. The traditional equation of the Ripley's K function is

$$\hat{K}(r) = \frac{A}{n^2} \sum_{i \neq j} I_r(d_{ij}),$$

where d_{ij} is the distance between two points, i and j and $I_r(d_{ij})=1$ if $d_{ij} < r$ or is '0' if the distance is less than the radius. The number of events is represented by n and A is the defined area (Bailey and Gatrell 1995: 92; Baxter 2003: 166). If correcting for the edge effect within the equation, the Ripley's K function is calculated as

$$\hat{K}(r) = \frac{A}{n^2} \sum_{i \neq j} \frac{I_r(d_{ij})}{w_{ij}},$$

where $\sum_{i \neq j} I_r(d_{ij})$ is the sum of distance between points i and j within the defined distance band (radius) r , and w_{ij} is the proportion of the perimeter of a circle centred on point i and passing through point j that lies within the study region (Bailey and Gatrell 1995: 92; Baxter 2003: 167). The more common way to calculate the Ripley's K function is by transforming the cumulative K-distribution to

$$L(r) = \sqrt{\hat{K}(r)/\pi} - r,$$

where r is the radius (Bailey and Gatrell 1995: 94; Pélissier and Goreaud 2001: 102; Baxter 2003: 167; Conolly and Lake 2006: 166).

If $L(r)$ is equal to zero, the distribution is random. If the output is less than zero, a regular pattern exists, while an output greater than zero indicates that the distribution is clustered (Ripley 1981: 160; Bailey and Gatrell 1995: 94; Pélissier and Goreaud 2001: 102; Baxter 2003: 167; Conolly and Lake 2006: 167).

The use of the Ripley's K statistic in archaeology, though limited, has some utility in settlement studies. The Kythera Island Project (KIP) sought to map settlements that dated to Classical, Roman, Medieval and Venetian periods (Bevan and Conolly 2006: 222). Bevan and Conolly (2006: 225) noted that when they applied the Ripley's K method, the buildings within the settlements were clustered together, but when they looked at the island as a whole, the settlements seemed to have a regular distribution (Bevan and Conolly 2006: 225). Although the Ripley's K method was useful in detecting patterns within the settlements and landscapes as a whole, since the sites were not separated into time periods one cannot get a clear picture of the social organization of these groups. Chronologically separating the data and repeating the analysis is needed to detect site selection and organisation for each cultural period.

Another example that demonstrates how the Ripley's K method is applied includes Pélissier and Goreaud's 2001 study on plant ecology. They examined forest regions in France and India to test the spatial heterogeneity of tree growth since survival is dependent on the spatial interactions between the trees (Pélissier and Goreaud 2001:102). The examination of a one hectare plot of a 140 year old stand of trees in the Haye forest in France showed clustering, but when the study region was divided into sub-plots ranging from 0-8 m, the spacing was more homogeneous. According to Pélissier and Goreaud (2001: 104), natural processes are highly dependent on local environments (soil, topography, etc.). The Ripley's K statistic was very useful to assist in detecting spatial patterns that reflected the heterogeneity of these regions, which is important to forest survival.

Moran's I Statistic

Moran's I (Moran 1950) is a statistical method that measures the degree of spatial correlation between points. This technique looks at regions within the study area and measures the spatial proximity between them (Kvamme 1990: 199; Baxter 2003: 170). The Moran's I test will calculate whether the archaeological remains are positively correlated (clustered) or are negatively correlated with no spatial correlation at all (Hodder and Orton 1976: 178; Kvamme 1999: 199; Baxter 2003: 170; Conolly and Lake 2006: 158; Rogerson 2006: 233). The Moran's I statistic is calculated as

$$I = \frac{n \sum_i \sum_j w_{ij} (y_i - \bar{y})(y_j - \bar{y})}{\left(\sum_i \sum_j w_{ij} \right) \sum_i (y_i - \bar{y})^2},$$

where n is the region(s) (or archaeological remains), w_{ij} is a measure of spatial proximity between i and j , which is an inverse distance measure $1/d_{ij}$ and y is the variable being studied (Moran 1950; Kvamme 1990: 199; Baxter 2003: 170; Conolly and Lake 2006: 158; Rogerson 2006: 232). The Moran's I statistic can also be expressed in a simpler form by first transforming the variable of interest into a z-score ($z = (y - \bar{y})/s$, where s is the standard deviation) and calculating it as

$$I = \frac{n \sum_i \sum_j w_{ij} z_i z_j}{(n-1) \sum_{i=1}^n w_{ij}}$$

If the given output is positive, then the distribution is said to have a strong spatial correlation, where high values are located next to other high values. A negative output indicates that the remains of high values are located near low values, but this is considered to be a rare occurrence. Distributions with an output of zero have no spatial correlation (Hodder and Orton 1976: 178; Kvamme 1999: 199; Baxter 2003: 169; Conolly and Lake 2006: 158; Rogerson 2006: 233).

The variance and z-test of the Moran's I method can also be calculated to determine the statistic's significance and would follow the same rules that were outlined in the nearest neighbour section. The variance is calculated as

$$V[I] = \frac{n^2(n-1)S_1 - n(n-1)S_2 + 2(n-2)S_0^2}{(n+1)(n-1)^2 S_0^2},$$

where the variables S_0 , S_1 and S_2 are written as

$$S_0 = \sum_i \sum_{j \neq i} w_{ij}, \quad S_1 = 0.5 \sum_i \sum_{j \neq i} (w_{ij} + w_{ji})^2 \quad \text{and} \quad S_2 = \sum_k \left(\sum_j w_{kj} + \sum_i w_{ik} \right)^2,$$

where k is another point in the distribution. Once the variance has been calculated, the z -test can be calculated as

$$z = \frac{I - E(I)}{\sqrt{V[I]}}$$

where the expected value of I , $E(I)$, is written as

$$E(I) = \frac{-1}{n-1}$$

The Moran's I statistic was used to study the terminal distribution of dated monuments in Lowland Classic Maya sites to determine if there was a link between the cessation of building these monuments and the Classic Maya collapse. Bove (1981) originally carried out a trend surface analysis, which also uses point data to separate broad scale variations from local variations, on 47 lowland sites and determined that the collapse followed a west to east movement. Whitley and Clark (1985) used Moran's I method to test Bove's hypothesis. The same 47 sites were examined and the area was divided into 17 study units with at least one site falling within each unit (Whitley and Clark 1985: 386). The Moran's I method failed to show any indication of a spatial correlation in this case, and therefore, did not support the notion that there was a simple geographic pattern for the terminal distribution (Whitley and Clark 1985: 390).

These data were later re-examined by Kvamme (1990) who came up with different results by changing the weight of the spatial proximity between the point data to include the Euclidean distance between two points. He found that there was in fact a positive correlation in the data, but that the nature of that trend was not detectable based on this statistical test (Kvamme 1990: 203). This shows that the Moran's I method should be used with caution and with other statistical procedures.

The Moran's I statistic was also used by Sokal et al. (1989) to detect spatial patterns in gene frequencies in Europe, from the Neolithic to modern times. Their study encompassed a large region of Europe, in which 59 different gene frequencies were tested in order to understand where they developed over time and their geographical spread. By using the Moran's I method, Sokal et al. (1989: 288) found that strong spatial patterns for most of the frequencies were apparent. The gene frequencies displayed significant heterogeneity and a strong decline in the overall genetic similarities over geographic distances. There were also well defined clusters in certain areas. These results confirmed that migration during the Neolithic time period was an important factor in the formation of modern gene pools in Europe and that these early major migrations can still be detected today (Sokal et al. 1989: 292).

Getis-Ord General G_i Statistic

The Getis-Ord General G_i method (Getis and Ord 1992; Ord and Getis 1995) is also a spatial autocorrelation statistical method. Using this technique allows researchers to determine whether a particular location and its surrounding regions have higher than average values on a variable of interest. It measures the concentration (or lack of concentration) of all pairs in a distribution by looking at the distance between the two (Getis and Ord 1992: 195). Essentially, this statistic looks for areas of intense clustering, or 'hot spots', in the distribution (Getis and Ord 1992: 190; Ord and Getis 1995: 288; Rogerson 2006: 240).

The Getis-Ord General G_i statistic is defined as

$$G_i(d) = \frac{\sum_j w_{ij}(d)x_j}{\sum_j x_j}, \quad j \neq i.$$

Binary weights are used, where $w_{ij} = 1$ if j is within a distance, d , of i . The weight would be zero if these conditions are not met. The numerator is the sum of all x_j within a distance of i , but not including x_i . The denominator is the sum of all x_j , not including x_i (Getis and Ord 1992: 190; Ord and Getis 1995: 288). The sum of all weights (w_{ij}) is written as

$$W_i = \sum_{j \neq i} w_{ij}(d).$$

When $\bar{x}(i)$ and $s^2(i)$ are set to

$$\bar{x}(i) = \frac{\sum_j x_j}{(n-1)} \quad \text{and} \quad s^2(i) = \frac{\sum_j x_j^2}{n-1} - [\bar{x}(i)]^2,$$

the variance can be calculated as

$$\text{Var}(G_i) = \frac{W_i(n-1-W_i)}{(n-1)^2(n-2)} \cdot \left[\frac{s(i)}{\bar{x}(i)} \right]^2.$$

By including this measure, the statistic is redefined and calculated as

$$G_i(d) = \frac{\sum_j w_{ij}(d)x_j - W_i\bar{x}(i)}{s(i) \left\{ [(n-1)S_{1i} - W_i^2] / (n-2) \right\}^{1/2}}, \quad j \neq i,$$

(Getis and Ord 1992: 191; Ord and Getis 1995: 289; Rogerson 2006: 240), where S_{1i} is written as

$$S_{1i} = \sum_j w_{ij}^2, \quad j \neq i.$$

The z-test of this statistic is calculated as

$$z = \frac{G_i - E(G_i)}{\sqrt{Var(G_i)}}$$

where $E(G_i)$ is calculated as

$$E(G_i) = W_i / (n - 1).$$

This formula will indicate the significance of the statistic as outlined in the previous sections. The z-test output indicates if the distribution is random, regular or clustered. If the output yields a large positive z , there are a large number of points within a specified distance. If there is a large negative z , then there are a small number of points within the specified distance (Getis and Ord 1992: 192; Ord and Getis 1995: 288).

This calculation is different from the statistical methods mentioned above because it uses a local function, while the other methods use global functions (Getis and Ord 1992: 190; Ord and Getis 1995: 287; Rogerson 2006: 239). Global functions are general methods that are used to test the overall pattern in a large region by looking at the degree of deviation from a random pattern. Local functions, on the other hand, are used to evaluate the degree of clustering around a particular point in the distribution (Getis and Ord 1992: 287, Rogerson 2006: 239). Because different statistical methods can look at particular aspects of the distribution, a better interpretation of the patterns can be made. Getis and Ord (1992) stress that even though this statistical method measures spatial association in a distribution, it is important to use it in conjunction with other statistics to better understand the spatial distribution of the variable being measured.

The Getis-Ord General G_i method is relatively new, but should prove helpful “in any context where assessments of spatial scale can be used to infer details of the

processes responsible for an archaeological phenomenon's deposition" (Premo 2004: 864). Premo (2004: 863) determined that there was a certain degree of spatial correlation in the terminal date data for the Lowland Classic Maya monuments when he used this method (Premo 2004: 863). Since the General G_i method is a local spatial statistic, a more detailed analysis could be performed, which gave different results when compared to the Moran's I outputs presented by Kvamme (1990) and Whitley and Clark (1985). This example attests the need to carefully select the most suitable spatial analytical technique to examine the data.

The Getis-Ord General G_i statistic has also been used to examine housing prices in the San Diego County and Sudden Infant Death Syndrome (SIDS) in North Carolina (Getis and Ord 1992), as well as the occurrence of AIDS cases in the San Francisco area (Ord and Getis 1995). It is reasonable to assume that it can also be used to examine the distribution of remains from archaeological sites.

K-means Statistic

K-means is a method that partitions point data into a specified number of clusters that are defined by the researcher (Kintigh and Ammerman 1982: 39; Aldenderfer and Blashfield 1984: 47; Shennan 1997: 251; Conolly and Lake 2006: 171). The centre of each cluster is randomly selected and the remaining points are added to the cluster centre they are nearest to. Since this is a simple method to determine areas of clustering at an archaeological site, it is frequently used when performing spatial analyses.

The K-means method was used by De Bie et al. (2002) to delimit clusters of artefacts found at the site of Rekem in Belgium and determine if there were any spatial patterns, such as knapping areas or habitation zones. Due to the nature of the flint

knapping process, there is not normally more than one definitive cluster, but De Bie et al. (2002: 146) showed that this method is useful in determining the dispersal patterns generated by the activity. The results from the K-means cluster analysis denoted the location and orientation of the knapper. Furthermore, the researchers concluded that the majority of the activities took place around the hearths, inside the dwellings in the habitation area (De Bie et al. 2002: 157).

Johnson and Johnson (1975) also used K-means to test seriation chronologies on Kansas City Hopewell ceramic data by plotting them in two-dimensional space. Data from four sites along a 20 mile stretch of the Kansas and Missouri Rivers, along with radiocarbon dates and stratigraphic evidence, were used to determine to degree of seriation within the ceramics (Johnson and Johnson 1975: 284). The K-means clusters were arranged on an x-axis plane and were used to compare the position of each sherd to see where they fit into the temporal seriation. They observed that the sequence of ceramic rims used in the K-means clustering matched the independently derived ceramic sequence based on the radiocarbon dates and stratigraphic evidence from the sites (Johnson and Johnson 1975: 294). In this case, K-means analysis was used to compare known evidence (radiocarbon dating and stratigraphy) in order to validate the ceramic chronology.

K-means analysis was undoubtedly useful in the visual interpretation of Rekem, but as De Bie et al. (2002: 163) stressed “no single method of spatial analysis can be satisfactory when used in isolation”. Since the user defines the number of clusters, bias is introduced into the data. Visually, there may be only ‘x’ clusters represented in the data, but it is not known if there are distinct clusters present within those groups as well. In

addition, the cluster shape is defined as a circle, irrespective of the true shape. The boundaries of clusters may not be well defined, which makes it difficult to identify clusters in complex data sets. When these limitations are taken into consideration, K-means analysis can be applied to some archaeological data, however, the results should be supplemented with other spatial analytical methods. Because of these limitations, this technique was not used to spatially examine the remains from the Fincastle Bison Kill Site.

Statistical Method Summary

Based on the examples discussed above, it is clear that archaeologists should use these statistical methods with caution and in combination. Furthermore, though they can yield interesting results, they need to be understood and validated in an archaeological context. For example, when knapping a tool, one can expect a clustering of a single raw material in one area of the site, where the knapper was sitting. The same can be said about the butchering practices a culture employed. When butchering an animal carcass certain tasks may have been assigned to one individual. If that individual was responsible for tongue removal, for example, the archaeological record may reveal an abundance of mandibles and hyoids in one area of the site.

The main challenge of the utility of statistical approaches relates to the amount of data archaeologists need to examine. An archaeologist wishing to determine if clustering existed at a site may have thousands of points to work with. Calculating the statistics by hand is not feasible. Thankfully, there are a number of programs that can perform these calculations, such as the Statistical Package for the Social Sciences (SPSS), S-Plus, the R programming language, Microsoft Excel and Geographic Information software. The latter

is especially important because all the statistical methods discussed in this chapter are available within the program.

Geographic Information Systems

A Geographic Information System (GIS) was first developed in the early 1960s by the Canadian government, under the leadership of Dr Roger Tomilson (Foresman 1998: 4; Tomilson 1998: 21). Since there was no method or technology to record spatial phenomena, the Canadian government stepped forward and accomplished what was once thought to be impossible, i.e., recording all geographical data that was used in land management decisions (Tomilson 1998: 22). While the commercial and public sectors played a pivotal role in the early development of GIS, it has been the academic sector that has been able to take more risks and therefore, develop new technologies (Chrisman 1998: 33). GIS is now used in many disciplines to accomplish a variety of goals.

A GIS allows for the collecting, storing, querying, analyzing and displaying of geospatial data (Burrough and McDonnell 1998: 11; Kvamme 1999: 154; Ebert 2004: 319; DeMers 2005: 5; Chang 2006: 1). With regard to spatial analysis, geospatial data are used to represent real-world phenomena for purposes of explanation, planning, prediction or description (Wegener 2000: 5; Goodchild 2005: 3; Conolly and Lake 2006: 45). In earlier years, specific spatial software was custom-designed for particular datasets that were being spatially analyzed (Maguire 2005: 20). As the popularity of analyzing spatial data increased, generic software was developed to provide a means of examining a wide range of problems (Maguire 2005: 20). GIS was the impetus to integrating spatial analysis into the generic software. The spatial nature of the software makes it the platform of choice for performing this type of analysis (Goodchild 2005: 3; Maguire

2005: 20). It simply makes sense to use it to examine the spatial data from archaeological sites.

GIS use in archaeology is still in its infancy (Middleton 1998: 30; Lieff 2006: 7), but some form of spatial analysis has always been used to explain cultural activities at a site. Hand sketched maps and artefact plots were initially used for spatial analysis. These were later drawn using a computer-assisted drawing program (e.g. AutoCAD, CorelDraw, Adobe Illustrator, etc.) although they still had some severe limitations. Counting remains on these hand- or computer-assisted drawn maps was the predominant method of acquiring the data needed to perform spatial statistical analysis to interpret the site (Hodder and Orton 1976; Orton 2000). If the excavated archaeological material was dense, the map was often too crowded, making interpretation difficult (Hivernel and Hodder 1984: 97). Since these maps did not have an electronic spatial database linked to them, detailed analysis had to be done by hand. Using a GIS for the spatial analysis offered new ways to work with large data sets in order to detect spatial phenomena (Ebert 2004: 335).

There are now several examples where GIS has been applied to archaeological data. Middleton (1998) provided an overview of the use of GIS in archaeological projects. Since his thesis research, several more projects have incorporated a GIS to handle the geospatial data, though one would expect to see more in the literature.

A GIS software program, ArcGIS, was used to examine the Chalcolithic period settlement distribution in the Southern Levant, Israel. Fletcher (2008) used spatial statistical methods (nearest neighbour, Moran's I and Getis-Ord General G_i^*) in ArcGIS to study the degree of clustering in the settlement distribution. He began with the premise

that settlements tend to cluster around a larger centre that supplied them with services and resources. This is generally known as a central place theory, which was first defined by Walter Christaller in the 1930s (Hodder and Orton 1976: 55; Johnston 1979: 54-55; Fletcher 2008: 2051). Fletcher was able to show that at a large scale, the sites in the Southern Levant were clustered around ephemeral streams rather than larger centres. However, at smaller scales, he was able to discern a different pattern: the distribution was random (Fletcher 2008: 2056).

Moyes (2002) also used a GIS to investigate archaeological spatial distributions. She used the GIS to visualize as well as perform spatial analysis on the data from the Terminal Classic Maya ceremonial cave site in Belize. The GIS also allowed her to display the entire cave chamber on one screen, instead of having to look at different areas of the site separately. She combined this visualization with statistical methods in the GIS (K-means and local density analysis) to determine the degree of artefact clustering in the cave (Moyes 2002: 13). She concluded that the artefacts were clustered around areas of significance, such as hearths and natural stone altars (Moyes 2002: 15). She noted that even though this study would have been possible using the paper maps, the amount of time needed to accomplish this task would have been much longer, and the precision and accuracy would have been lost. She also noted that the visual representation of the site could have been done in other programs, but the geo-referencing of objects and spatial analysis would have had to be performed in the GIS (Moyes 2002: 15). Therefore, a GIS was ideal for this project because it was able to execute all types of spatial analyses in a single program.

Wheatly examined the construction of long barrows on the Salisbury Plain and the Avebury region to determine if they were placed in locations that took into account the visibility of other barrows in the area (Wheatly 1995: 176). Using a digital elevation model (DEM), a line of sight was placed on each barrow in the area and the output showed all visible areas in the landscape, called the viewshed. All of the outputted viewsheds were combined into a single map to reveal which barrows were visible from one another (Wheatly 1995: 177). The results showed that barrows constructed in the Salisbury Plain tended to be located in areas that were visible from the other barrows, while the barrows constructed in the Avebury region showed no evidence of this relationship (Wheatly 1995: 182-183). Other archaeological evidence is needed to explain why there would be a difference between the two areas, but it may be a deliberate cultural difference (Wheatly 1995: 183).

Kvamme (1996) used a GIS to examine lithic tool scatters in the desert region near Grand Junction, Colorado. His six hectare study area was ideal because it contained multiple high density flake debris clusters. The area also lacked vegetation, had numerous visible surface artefacts due to deflation and was not disturbed by artefact collectors thanks to its remote location (Kvamme 1996: 41). The data collected from the archaeological site was entered into a GIS and overlaid onto a DEM of the site to see if patterns were apparent (Kvamme 1996: 43). The data on the lithic remains were organized according to size within the GIS. Kvamme (1996: 46) determined that the smaller flakes were grouped in the centre of the cluster, while the larger flakes occurred on the cluster margins. This output supported the theory that larger flakes removed from a core would take more force and, therefore, would travel farther than smaller flakes

(Kvamme 1996: 50). These results were based on GIS visualisation techniques alone, with no statistical test to verify the cluster patterns (Kvamme 1996: 46).

To validate his results, Kvamme (1996) applied the Moran's I statistical method to determine the degree of correlation between the variables within the study area. Based on his results, a positive association exists for each variable within the study area (Kvamme 1996: 49). He validated his results even further by carrying out a flint knapping experiment to see if the clusters found at the site were similar to the action itself (Kvamme 1996: 53). Lithic scatters from four experiments were mapped and entered into a GIS. The visual outputs from these experiments were then compared to the field data collected from the site (Kvamme 1996: 56). The results from this experiment corroborate the hypothesis that the larger flakes travelled the farthest due to the knapping force (Kvamme 1996: 56). The combination of tests strengthened the interpreted results.

In Balme and Beck's 2001 study, the spatial distribution of charcoal and sediment starch over horizontal space at the Petzke's Cave rockshelter in New South Wales, Australia was examined. Since there was no visual way to determine if the charcoal in the cave was created from natural fires or produced by cultural activities, Balme and Beck (2001: 158) compared the charcoal fragments with starch concentrations from sediment samples collected at the site. The top three centimetres of the site was excavated from 47 square metres and all features, charcoal and sediment samples were recorded, analyzed and entered into a GIS. Within the GIS, the charcoal and starch remains were interpolated and output as a visual map to determine where areas of activity had occurred (Balme and Beck 2001: 161). The results showed that the starch and charcoal had an inverse relationship. Areas with high charcoal densities had low quantities of sediment starch and

areas with high starch contents had low quantities of charcoal (Balme and Beck 2001: 164). Since charcoal is assumed to be associated with hearths, it could be that the heat destroyed any starch that was in the sediment (Balme and Beck 2001: 164). Areas of high starch content could have been where plants were stored and processed. Using GIS to study such sites may reveal what was not apparent in simple maps.

A GIS was also used to examine cultural patterns in the data from a conductivity and magnetic susceptibility test of sediments to determine if they experienced anthropogenic alteration (Ladefoged et al. 1995). Conductivity measures the ease with which an electrical current flows through material. Sediment conductivity is dependent on the structure and porosity of the sediment fabric, dissolved ion content, the amount of water and human alteration (Ladefoged et al. 1995: 472). Magnetic susceptibility looks at the magnetization of sediments, which is dependent on the iron compounds that are present in the soil. The burning and the alteration of reducing and oxidizing conditions can change the magnetic susceptibility of sediments (Ladefoged et al. 1995: 472). Data from two sites in New Zealand were collected. The sites were measured with a grid, therefore, x, y and z coordinates of conductivity and magnetic susceptibility measurements were able to be entered into a GIS (Ladefoged et al. 1995: 471). Excavations revealed a five-phase occupation sequence, with domestic structures overlying four sets of stratified food storage pits at the site of Ureturituri in 1993 (Sutton 1994). The spatial patterns identified in the GIS analysis revealed two areas that could have been ditch and bank features for defensive purposes, a dense rock concentration indicative of large rock-filled ovens and smaller anomalies that may represent pits (Ladefoged et al. 1995: 476-477).

The GIS analysis of the conductivity and magnetic susceptibility data from Fort Resolution, a European era site, identified various areas within the sediment that corresponded to the archaeological remains of the previous military structures noted in the historic literature (Ladefoged et al. 1995: 479). By examining the conductivity and magnetic susceptibility survey results within a GIS, a greater understanding of the cultural features was gained. Moreover, these methods can be used to assess the significance of archaeological resources and be the basis for planning future excavations.

GIS has also been used by archaeologists trying to recreate past events, as was the case for the Bonfire Shelter study (Byerly et al. 2005). The shelter is located at the base of a cliff that is 26 m high, near Langtry, Texas. The Paleoindian site was originally excavated in 1963 and 1964 by Dibble and Lorrain (1968) who proposed it was a bison jump. Bison jumps commonly are found in the northern and northwestern Plains in the later Prehistoric time periods (Byerly et al. 2005: 597). A Paleoindian jump would make it unique. The site was re-examined by Byerly et al. (2005) to determine if this was in fact the case.

Their study began with a high resolution digital elevation model (DEM) of the Langtry area. From the DEM, slope and least-cost pathways were calculated (Byerly et al. 2005: 600). A least-cost pathway is defined as a route that minimizes a specific variable, in this case slope and the effort of crossing a given land unit (Byerly et al. 2005: 601). The hunters would have needed a relatively straight, level, unobstructed stretch of land to drive the bison off the cliff. Viewshed analysis was also incorporated into the GIS with an offset of 1.7 m, the estimated height of *Bison antiquus*. The result showed that routes from the north or northeast were the most suitable for drive lanes although the

viewshed revealed that the cliff was visible 200 m from the edge (Byerly et al. 2005: 603). The view of the cliff was again obstructed from 200 to 25 m from the edge, but there may have been enough distance for the herd to avoid the cliff unless the hunt took place when environmental conditions reduced visibility.

The GIS results moderately support the hypothesis that Bonfire Shelter was used as a bison jump if the environmental conditions were optimal but place doubt in Dibble and Lorrain's suggestion. The faunal remains were also re-examined to test this theory (Byerly et al. 2005: 605). Data from the faunal analysis suggests that Bonfire Shelter was a secondary processing site where the animals were transported from the primary kill site (Byerly et al. 2005: 618). The under-representation of certain elements of the bison, such as the lower limbs and the ribs, as well as the evidence for marrow extraction do not point to a kill site (Byerly et al. 2005: 618). It must be noted, however, that the 1983-84 faunal remains were not included in the analysis and that the site is subjected to fluvial processes that could have destroyed archaeological evidence (Byerly et al. 2005: 618). This aside, the results from the excavation of the faunal remains do not support the bison jump theory.

The spatial context of the archaeological remains at the EfPm-27 bison kill and processing site were difficult to interpret due to the large number of faunal remains. Wickham (2005) used a GIS to delimit several kill events superimposed on the same surface. The attribute data she collected through detailed faunal analyses included the examination of the cow/calf remains in comparison to bull remains, the butchering patterns and the absence or presence of certain skeletal elements (Wickham 2005: 235).

This allowed her to spatially locate spring and winter kill events at the site even though the faunal remains were sometimes located in the same area.

Middleton (1998) used a GIS to delimit trends and occupation levels at Head-Smashed-In Buffalo Jump in Southern Alberta. Head-Smashed-In was an ideal site to use because it is a multi-occupational site. This site also has evidence for primary and secondary butchering activities, tool manufacture and re-sharpening and burning areas (Middleton 1998: 54). Middleton (1998) concluded that over time, the lithic technology evolved and the types of raw materials used changed. His research also revealed that there was several tool sharpening areas. The GIS analysis of the faunal remains showed that there were two major burnings, as well as marrow processing areas (Middleton 1998). Using the GIS, in this case, was beneficial to delimit temporal periods as well as specific cultural activities that were present at the site.

A GIS has also been used to examine intrasite spatial variation of artefact relationships that are computationally difficult. In the Omo Kibish area of Ethiopia, two sites were excavated and their horizontal spatial distributions examined (Sisk and Shea 2008). Both assemblages were dominated by stone artefacts and refitting projects were successful (Sisk and Shea 2008: 487). At the Kamoya's Hominid Site, a small assemblage of stone artefacts was recovered, with 27 refitted artefact sets (Sisk and Shea 2008: 492). The spatial analysis of the site involved plotting the artefacts within a GIS and separating the artefacts into raw materials and artefact types: cores vs. flakes and debris (flakes or flake fragments <30 mm). There was no definitive patterning evident due to low artefact counts, with the exception of one dense concentration 10 cm in diameter (Sisk and Shea 2008: 493). When Sisk and Shea (2008: 493) looked at the

refitting and spatial analysis together, they concluded that the artefacts were rapidly buried under low energy conditions. There would not have been as many tightly clustered refits if there were high energy conditions.

At the Bird's Nest Site, 386 stone artefacts and 728 pieces of debris were uncovered during the excavations, with 23 refits (Sisk and Shea 2008: 493). The spatial analysis of this site revealed a north-south trend in the artefacts, as over half of the remains were uncovered in the northern area of the site. The artefacts may have been reworked by slope processes that deposited the lighter debitage away from heavier artefacts (Sisk and Shea 2008: 497). More likely, however, is that the spatial segregation reflects the stone knapping and tool discard behaviour, where the smaller artefacts were located close to where knapping occurred and were not transported elsewhere at the site (Sisk and Shea 2008: 497). This is supported by the fact that smaller debitage was located within the clustered areas, along with the larger artefacts. Their findings are interesting when compared to Kvamme's (1996) lithic scatter study and clearly warrant further investigation outside the focus of this thesis. This aside, using a GIS in conjunction with refitting techniques helped shed light on cultural site formation processes that occurred thousands of years ago.

Though few site projects that used a GIS program have been published thus far, it is easy to see the value in using such software. This spatial analytical program can be used at any archaeological site with recorded spatial data, no matter its location or time period.

Summary

Spatial analysis is an important part of archaeological interpretation. It is used to detect patterns in the archaeological data, which can assist in understanding the cultural activities that took place at a site or group of sites. Spatial analysis can be used at the micro (site) or macro (regional) scale, can examine the general distribution, and can incorporate measurements to achieve more robust results. There are biases associated with each statistical method, but using them in combination can negate this issue. Performing more detailed analyses to detect subtle patterns in the data are obvious.

Using a GIS to spatially analyze archaeological sites is a new advancement in archaeology. These systems have been used in previous archaeological work, but often for display purposes only. Using a GIS to create maps and statistically examine the spatial distribution of the archaeological data offers a clear advantage to cultural interpretation efforts. Since most GIS software packages have spatial statistics built right in, analysis should be relatively easy. To examine the use of a GIS to carry out these analyses, the archaeological remains at the Fincastle Bison Kill Site were used as a test case.

Chapter 3 - Methodology

Introduction

This chapter begins with an overview of the field research carried out as part of the Fincastle Bison Kill Site project. The ability to perform a detailed spatial analysis on the archaeological remains recovered from a site depends on the field methodology used. The field methodology was designed to obtain a large enough sample of archaeological remains to determine the cultural activities that took place at the site, and to perform spatial analytical techniques to interpret these activities.

Each remain that was found during the three excavation seasons was analyzed in the laboratory. Attribute information connected to the artefacts and ecofacts were entered into databases. This process is outlined in the laboratory analysis section of this chapter. These databases were then uploaded into the GIS thereby linking this information with the spatial data. The final section in this chapter, the GIS methodology, includes the steps taken to create the GIS, as well as carry out the spatial analysis of the archaeological remains to determine the cultural patterns at the site, and evaluate the usefulness of GIS in archaeology.

Site Description

The Fincastle Bison Kill Site (DIOx-5) is located approximately 100 km east of Lethbridge, Alberta (Figure 3.1). The site is within the low sand hills of a protected cattle grazing reserve on crown land. It is near the Fincastle Marsh, which supports a variety of bird species. Other mammals found in the area include antelope, coyote and deer. The

rattlesnake and the protected spade-footed toad are also local to the area. The Oldman River is located 3 km to the north.

The site sits within a prairie eco-zone where prairie grasses, cacti and other plants that require little moisture are found. The climate is classified as semi-arid, with monthly mean temperatures ranging from -9°C to 19°C, and an average annual rainfall of 400mm (Environment Canada 2008). Since the site experiences active aeolian processes, the sandy sediments and soils, vegetation and wind have played a large role in the development of the landscape.

During the Late Pleistocene, the area was covered by the Laurentide ice sheet (Beaty 1975: 63; Wolfe and David 1997: 207). During deglaciation, glacial melt water formed lakes along the ice sheet, leaving glacial lacustrine deposits behind as the lakes drained (Wolfe and Nickling 1997: 14; Muhs and Wolfe 1999: 187). These lake bed deposits were subsequently eroded by the southwestern winds that are prominent in southern Alberta and deposited in the dune fields (Beaty 1975: 72). The dune fields were eventually stabilised by vegetation, creating parabolic dunes (Wolfe and David 1997: 210; Wolfe and Nickling 1997: 12; Muhs and Wolfe 1999: 188). The site of Fincastle is located within one of these parabolic dunes.

The site has been known to the local ranchers and farmers for decades. Residents notified the Alberta Culture and Community Spirit, Historic Resources Management Branch when they discovered that the site was being looted in 2003. The Alberta government organized a team comprised of volunteers from the Archaeological Society of Alberta (Lethbridge Centre) under the supervision of Dr. Shawn Bubel from the University of Lethbridge to survey the previously undocumented site and assess the

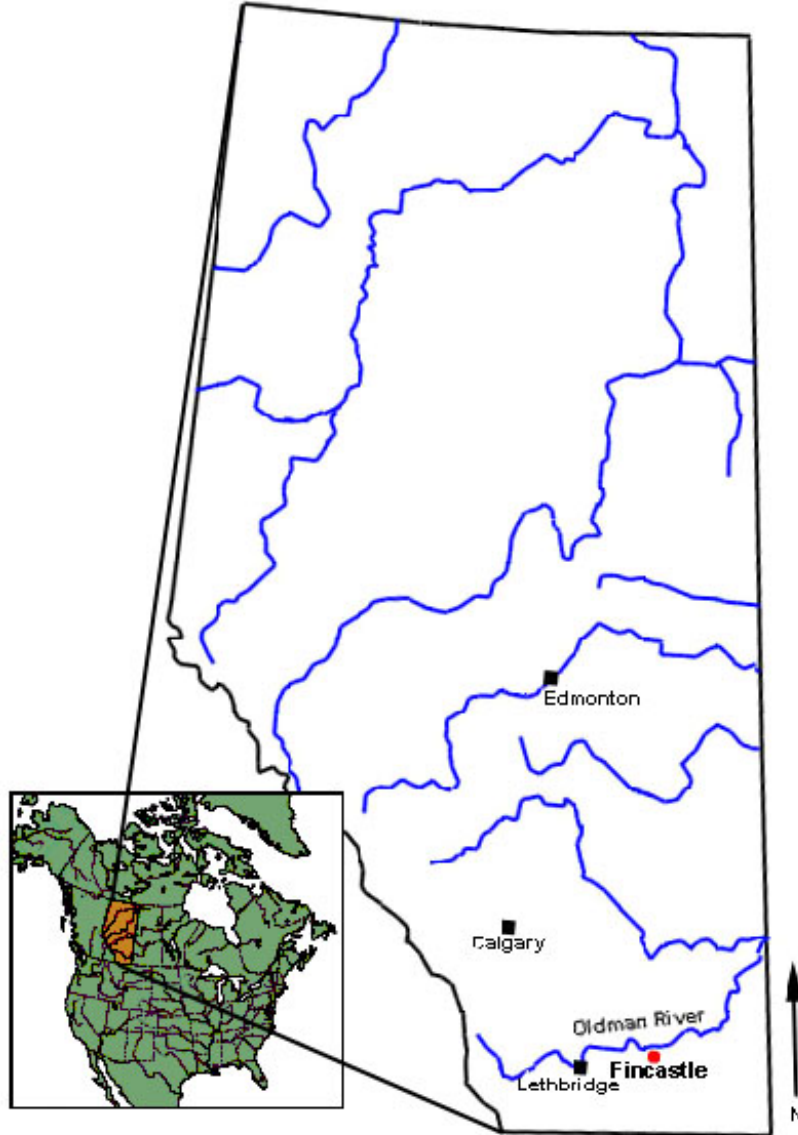


Figure 3.1: The location of the Fincastle Bison Kill Site, approximately 100 km east of Lethbridge, Alberta, Canada.

damage. A surface survey and collection was carried out to determine the cultural affiliation of the artefacts and denote areas of the site still in tact. After examining the archaeological remains collected and determining that there was contextual material, excavating the site became a high priority. Preparations for field work, organized as field

schools, were made for the following year before the site was destroyed by the looting activities.

Field Methodology

The main objective of the three field school seasons carried out in 2004, 2006 and 2007, was to obtain a large enough sample of the site to establish the cultural activities that took place and its chronological period. In order to achieve this, a meticulous field excavating and recording system was used. The dune was mapped using a Sokkia Total Station. Five base points were positioned around the dune and used as reference points within a relative coordinate system. The topography of the site was mapped using these points, creating a DEM and the excavation grid (Figure 3.2).

The 1x1 metre excavation units were positioned in the looted area and what looked to be untouched areas in the Western Area of the site order to locate *in situ* material. Meanwhile, six 50x50 cm shovel tests in the eastern part of the site revealed a well preserved bone bed. With low yields in the West Area, the excavation team was moved there.

A checkerboard grid system was set up in order to closely follow the stratigraphy in each excavation unit. The units were excavated in 5 cm arbitrary levels to gain detailed spatial information about the context of the archaeological remains. Marshalltown trowels were used until the excavators hit the bone bed. To expose the dense concentration of faunal remains, a variety of other tools were used, including bamboo skewers, paintbrushes, dental picks and spoons. All of the sediment removed from the unit was put into buckets that were screened through a 1/8 inch mesh. Using smaller mesh sizes ensured that small artefacts, such as micro-debitage, were recovered.

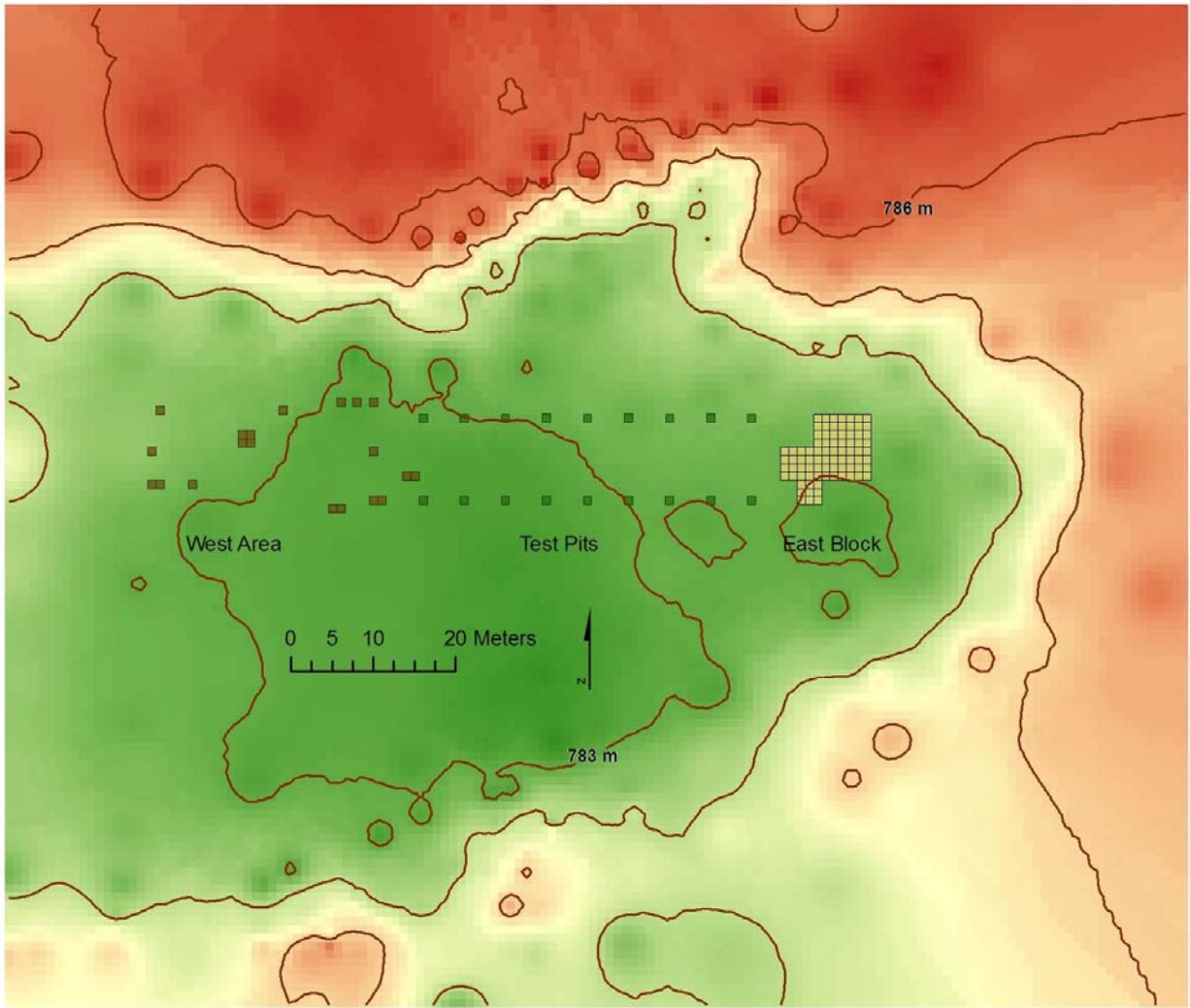


Figure 3.2: The DEM of the sand dune created from the points measured with the Total Station. The contours represent a 1 m change in elevation. The units were laid out using the Total Station.

Eighteen test pits were excavated in the 2006 and 2007 field seasons to stratigraphically connect the West Area (WA) with the East Block (EB) (Figure 3.2). Two of these test pits were expanded to 1x1 m units because of the quantity of material exposed. A total of 101 1x1m units were excavated over three field seasons providing a large sample of the Fincastle Site.

The three main types of archaeological remains recovered from the site are faunal remains, lithic artefacts and fire-broken rock (FBR). Lithic artefacts include projectile points, small and large lithic tools, and the debitage (waste flakes from tool manufacture or re-sharpening). Hammer stones, anvils and choppers made up the large lithic tool group, which were used to smash open bone to process the bison carcasses and to make and retouch lithic artefacts. The majority of the small lithic tools are scrapers and retouched flakes. Projectile points and debitage make up the rest of the lithic assemblage. The majority of the lithic artefacts were made from brown chalcedony (which is likely Knife River Flint), though Swan River chert, quartzite, obsidian, Montana cherts, petrified wood, and a variety of other cherts were also used.

Bones were the most abundant remain found at the site of Fincastle. Fragments of *Bison bison*, or the Plains bison, dominate the sample recovered. Canid and rodent remains were also found, but the latter are assumed to be modern as their burrows were seen cutting through the stratigraphy of the site. The fire broken rocks were found within the bone bed, but not as part of a defined hearth feature. Ten intentionally placed bone upright features were also found at the site, the function of which are unknown at this time.

When an artefact was found *in situ* (in its exact location after burial), its spatial location was recorded. The northing and easting coordinates of the artefact's midpoint was measured in centimetres from the edge of the unit. The elevation was obtained from the unit's datum peg and recorded as reading below datum (BD). The datum height for the unit was referenced to the base points.

All details, including the measurements of the archaeological remains, were meticulously recorded in the field in a variety of ways in order to reduce human error. Information regarding the excavation of each 1x1 metre was recorded in a field book. Notes on the sediments, stratigraphy and the archaeological remains, whether they were found *in situ* or pulled from the screened sediment, were recorded. Each identifiable remain received a unique field number and its north and east coordinates were noted, its depth below datum, along with any other important information associated with it. All remains were placed in individual bags and labelled with the date, unit number, field number, northing, easting, depth below datum (BD), the type of archaeological remain and other notes of interest.

In addition to the field books and archaeological remain bags, the level depths, the types of remains found, their numbers, photographs taken, the sediment/soil types and any cultural features found within each 5 cm level of the unit were recorded on a standard level record form. Identifiable *in situ* archaeological remains were also mapped on level graphs, or plans, at a 1:5 scale on millimetre graph paper (Figure 3.3).

All identifiable fauna were mapped, regardless of size. Any unidentifiable fauna larger than 5cm were also mapped. FBR over 2cm were mapped as well. All lithics (debitage and tools) were mapped regardless of size. Each mapped remain was labelled on the level graph with its unique field number to correlate it with the field book records and the artefact bag. A standard legend was used, where faunal remains were drawn as open polygons, tools as shaded polygons, FBR as crosshatched polygons anddebitage as an 'x'. The graphed level plans serve as a permanent record of the location of remains

from the site. These became the base images that were digitized into a GIS program after the excavations were complete.

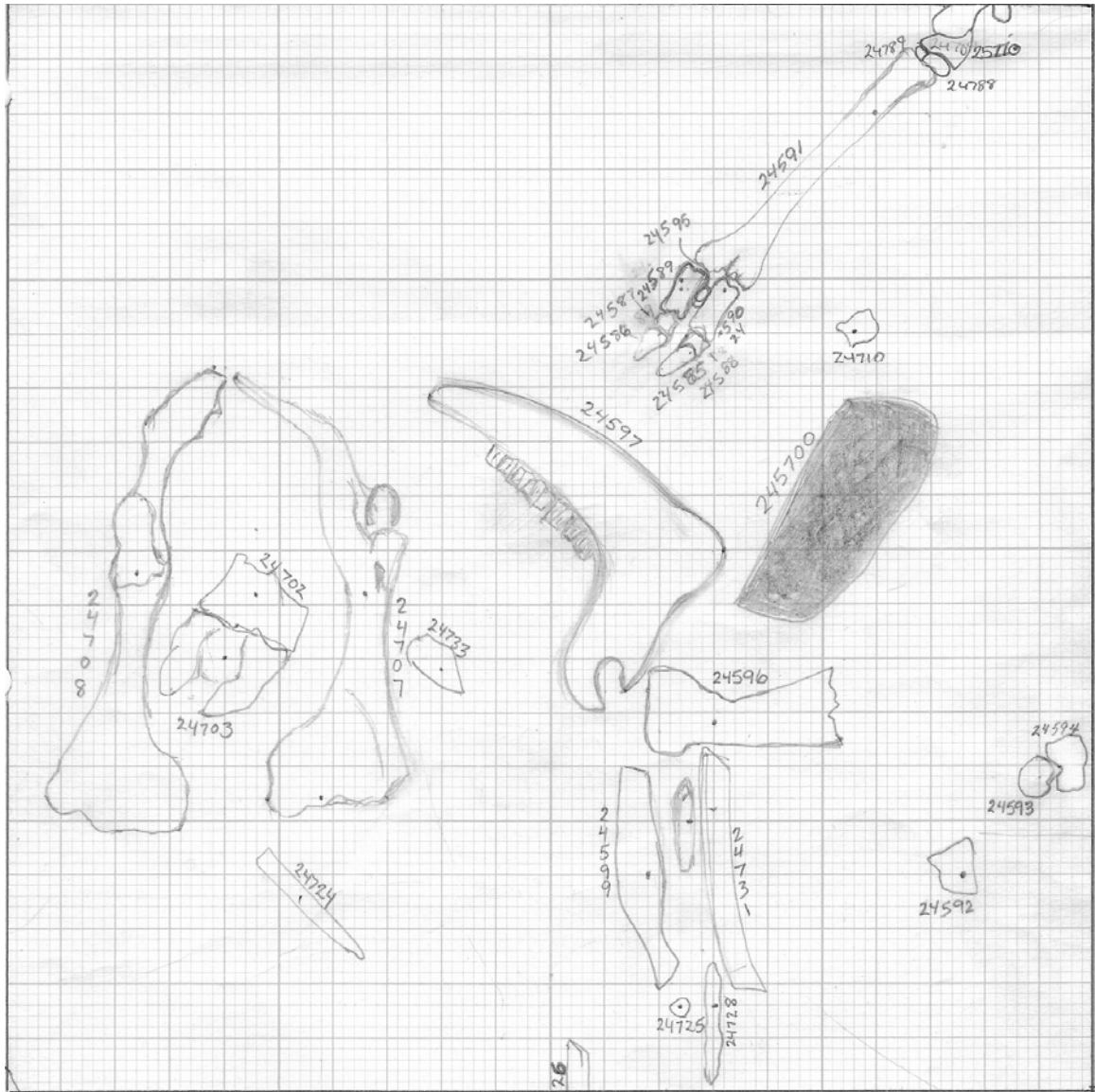


Figure 3.3: An example of a level graph drawn in the field.

Stratigraphy

Based on the stratigraphical context of the archaeological remains in the East Block, it is clear that the site was only occupied once (i.e., a single kill event). The

consistent style of the projectile points and tools found, the similar preservation of the material, the five very similar radiocarbon dates (see below) and the position of the single cultural layer above the sterile glacial lacustrine clays support this hypothesis. The stratigraphical context also attests to the fact that the dune postdates the use of the site: it was not there at the time of occupation. The bone bed was located under the dune in the northern extension of the site. Since aeolian processes were and still are active in the area, it is assumed that the dune migrated from the west and covered portions of the site before it was stabilised by vegetation.

In most areas of the site, there was a sandy AB soil horizon profile above the bone bed, which rested on a glacial lacustrine clay deposit. The A horizon was a dark brown silty sand that was usually capped with vegetation. The B horizon was light brown sand that varied in thickness depending on the position of the dune. The bone bed was found at the base of the B horizon. The glacial lacustrine deposit below was made up of gleyed gravelly clays.

Radiocarbon Dating

Seven samples of bone were sent to Beta Analytic Inc. for radiocarbon (^{14}C) dating. Two were selected shortly after the 2004 field season and the other five sent off in March 2008. Five of the seven samples came directly from the bone bed, though from different contexts across the site. The other two samples were taken 15 cm above the bone bed. It was important to date the bone bed itself, as well as confirm the temporal context of the West Area, and its connection to the East Block. Therefore, samples were selected from the East Block, including the northern extension of the bone bed and the West Area. Moreover, two of these samples came from upright cultural features.

The dates obtained from 2008 are consistent with the dates received in 2004 and confirm a single kill and butchering operation (Table 3.1). The site dates to 2,500 BP and falls within the Late Middle Prehistoric Period of Alberta. Samples 241256 and 241257 revealed inconsistent dates, but since their contexts are above the *in situ* material of the bone bed, they may have been contaminated through natural formation processes or come from another reworked site in the area.

Table 3.1: Radiocarbon dating results from the seven samples sent to Beta Analytic Inc. They confirm a ca. 2,500 BP date.

Beta Sample Number	Date Processed by Beta	Fincastle Excavation Context	Bone Element	Conventional Radiocarbon Age
201909	15/3/2005	East Block, Bone Bed (2004)	Lumbar Vertebra	2,540±50
201910	15/3/2005	East Block, Bone Bed, Upright (2004)	Metacarpal	2,490±60
241254	20/3/2008	West Area, Bone Bed (2004)	First Phalanx	2,490±40
241255	20/3/2008	West Area, Bone Bed (2004)	First Phalanx	2,610±40
241256	20/3/2008	Northern Extension of East Block, Above Bone Bed (2007)	Second Phalanx	1,310±40
241257	20/3/2008	Northern Extension of East Block, Above Bone Bed (2007)	Lone Bone Fragment	3,100±40
241258	20/3/2008	East Block, Bone Bed Upright (2007)	Metacarpal	2,680±40

Laboratory Analysis

All archaeological material excavated from the site was brought to the University of Lethbridge for analysis. Each archaeological remain was cleaned, catalogued, bagged and analyzed. Due to the high number of archaeological remains recovered from the Fincastle Bison Kill Site and the attribute information collected for each item, Microsoft

Access was used rather than Excel or Quattro Pro because it is better suited to handle the large amount of data and allows for advanced queries to be preformed.

Lithic Analysis

Lithic artefacts are defined as any culturally modified stone tool material (Andrefsky 2005: 11) and, therefore, include the debitage, small and large lithic tools and projectile points that were recovered from the site. The total numbers of lithic remains recovered during the three field seasons are listed in Table 3.2.

Varsakis (2006) examined the features of the 2004 and 2006 projectile points in detail (neck width, body length, raw material, etc.). From her study, she concluded that the projectile points were predominantly of the atlatl type and were constructed similar to Besant/Sonota types.

Table 3.2: Total number of lithic remains collected from the Fincastle Bison Kill Site over the three field seasons.

Excavation Area	Projectile Points				Lithic Tools				Debitage			
	<i>In situ</i>	<i>Sieve</i>	<i>Dist.</i>	<i>Total</i>	<i>In situ</i>	<i>Sieve</i>	<i>Dist.</i>	<i>Total</i>	<i>In situ</i>	<i>Sieve</i>	<i>Dist.</i>	<i>Total</i>
West Area	6	6	9	21	3	2	5	10	17	165	247	429
East Block	71	16	1	88	68	25	2	94	471	2,152	44	2,669
Test Pits	4	1	-	5	14	2	-	16	63	225	-	288
Total	81	23	10	114	85	29	7	121	551	2,542	291	3,384

The other lithic tools, including large lithic tools (hammerstones, anvils, choppers, etc.) and small lithic tools (scrapers, knives, borers, preforms, etc.), were later analyzed to study the cultural activities carried out at the site. Raw material type, typological classification, size and measurements (length, width, thickness, etc.) were examined. The hammerstones were likely used in tool manufacture, while the anvils and choppers were

associated with animal butchering, as were the scrapers and knives as suggested by Andrefsky (2005).

While the data linked to the projectile points and lithic tools are important to determine the cultural group associated with the site, the debitage can reveal cultural activities as well. As was the case for the tools, the raw material, length, width, thickness and weight were recorded, along with the flake features. These latter attributes included the flake type, how much cortex (the weathered surface of the raw material remaining on the flake) was present, the termination point of the flake (distal end) and its platform type. Dorsal scarring, or the negatives of previous flake removal seen on the dorsal surface of the flake, was another aspect that was studied to better understand the lithic reduction sequence. Based on these data, it may be possible to determine knapping, re-sharpening, and/or butchering areas. For example, if a tool became dull while butchering, the hunter could re-sharpen the tool, which results in the production of small flakes (debitage). Likewise, while butchering, small flakes may chip off when processing the carcass. It is important to recognize these areas of use at a site.

Fire Broken Rock Analysis

Fire broken rock (FBR) was closely examined to understand the use of fire at the site. While there was a large quantity of FBR recovered (Table 3.3), there were no definitive hearth features uncovered. This is most likely due to the strong winds that could have blown away any ash that was present. The FBR analysis involved examining the size of the rock, the material type, any crazing present, the percent of cortex still visible, the angularity of the rock and its colour.

Table 3.3: Total number of pieces of FBR collected from the Fincastle Bison Kill Site over the three field seasons.

Excavation Area	Fire Broken Rock			
	<i>In situ</i>	<i>Sieve</i>	<i>Disturbed</i>	<i>Total</i>
West Area	39	52	10	101
East Block	619	244	15	878
Test Pits	95	75	-	170
Total	753	371	25	1,149

Faunal Analysis

The identification and analysis of faunal remains from an archaeological site falls under the sub-discipline of zooarchaeology (Klein and Cruz-Uribe 1984: 1; Reitz and Wing 1999: 1; O'Connor 2000). The goal of zooarchaeological studies is to learn about the interactions that took place between the humans and animals, as well as the consequences of this relationship (behaviour and cultural adaptations) and their environment (Chaplin 1971: 143; Schmid 1972: 3; Hesse and Wapnish 1985: 5; Reitz and Wing 1999: 7). Animals can be used by humans in many ways, the most common being for nutrition as this is the basis of subsistence strategies (Reitz and Wing 1999: 7; O'Connor 2000: 145). Cultural context is very important in the interpretation of the faunal remains as the activities involving animals can be quite different. For example, activities within a temple, a midden, a house, a storage structure or at a kill site will result in a different faunal assemblage and context (Chaplin 1971: 56; Reitz and Wing 1999: 10).

As noted above, the faunal remains from the Fincastle Bison Kill Site make up the majority of the archaeological assemblage (Table 3.4). In the laboratory, the faunal remains were first processed before they underwent analysis. This involved sorting,

cleaning, counting, bagging and assigning each bone or group of sieved bones a catalogue number.

Table 3.4: Total number of faunal remains collected from the Fincastle Bison Kill Site over the three field seasons.

Excavation Area	Faunal Remains				
	<i>In situ</i>	<i>Sieve</i>	<i>Secondary</i>	<i>Disturbed</i>	<i>Total</i>
West Area	484	733	189	212	1,617
East Block	10,220	3,371	156	240	13,987
Test Pits	259	269	4	-	532
Total	10,963	4,373	349	452	16,137

Once the remains were processed, each identifiable faunal remain was examined to determine its element, age, side and species, and was also given a descriptive anatomical location using Brumley's (1991) Bone Unit classification System. This was done in order to know as much about the remain as possible, although not all the faunal remains were complete or preserved enough to obtain all of this information. The final steps in the analysis focused on the butchering features present on the bones. Watts (2008) concluded that both primary (disarticulation) and secondary (marrow extraction and grease rendering) occurred at the site based on the cut marks and fracture patterns present on several bones, as well as the contexts of the faunal remains.

The minimum number of individuals (MNI), number of identifiable species (NISP) and minimum number of elements (MNE) were also calculated. These numbers are used to estimate frequencies of taxa in faunal assemblages at the site (Lyman 1994; Reitz and Wing 1999). They can be used to pinpoint specialized areas, to determine subsistence strategies, to compare animal use by distinctive groups over space, as well as evaluate the relative importance of the animals in diets (Grayson, 1984: 16; Reitz and

Wing, 1999: 191). The minimum number of individuals (MNI) for the Fincastle Site was calculated based on the navicular cuboid. For the site as a whole, 60 bison were represented, 54 of which were found in the East Block.

GIS Methodology

ArcGIS was used to spatially analyze the site of Fincastle because this is currently the most frequently used GIS program in archaeology and other disciplines. ArcGIS is readily available to the business and academic sectors for a reasonable cost. The software is user friendly, which means that, with training, ArcGIS can be operated by all archaeologists. Moreover, it is a program that can be used to analyze all types of archaeological sites and remains no matter the cultural activities or temporal periods.

ArcGIS also offers spatial statistical methods that have been used in archaeology, along with newer techniques that are just finding their way into the discipline. Since ArcGIS has the capability to run the statistical methods that are frequently used to spatially analyze archaeological sites, it is possible to compare it to the traditional methods used. This section outlines how the GIS was used to spatially analyze the archaeological remains from the Fincastle Bison Kill Site.

Scanning the Level graphs

Each 5 cm level of an excavated unit had at least one level graph if there were *in situ* remains, but there were several plans drawn for the dense bone bed. A total of 1,014 level graphs were scanned as 256 grey shades, at a resolution of 200 dpi (dots per inch) so that the information could be differentiated. The images were saved as separate .tiff files, a format able to be displayed in ArcMap, a program within the ArcGIS software.

Each image was cropped to its 1x1m unit outline (Figure 3.3). It was very important to keep the level graph limited to the size of a unit so it lined up properly in the GIS. In cases where an archaeological remain was partly outside of the unit's boundary, it was cut. Remains outside the graph were digitized later by freehand. The cropped image was also saved as a .tiff file. Since ArcMap has difficulty reading files that have spaces in file names, an underscore () was used to separate the unit and the level (559N601E_Level1, for example).

Registering the Level Graphs

The .tiff files were then linked to their spatial positions and registered so they could be projected properly in ArcMap. In his preliminary work on the site, Lieff (2006: 36) created a world file in UTM 12 coordinates. Each image was linked to the world file that contained the geo-positioning information the digital (scanned) image corresponded to and was saved as such. This information was read by ArcMap when the image was opened into the GIS program. The northing information within the world file was used to position the bottom left corner, while the easting information provided the position of the upper right corner (Lieff 2006: 36).

It was important to carefully enter this information because the image could not be projected in ArcMap correctly if an incorrect coordinate was entered. With the coordinates of the first level graph of a unit figured out and changed in the world file, all other level graphs in that excavation unit were be easily registered, and the image name changed to correspond with the appropriate level.

Digitizing Archaeological Remains

Once the scanned level graphs were registered in their proper spatial location, the archaeological remains were digitized. This was done using the available tools in the GIS software to trace over the remains depicted on the level graph (Figure 3.4). Each archaeological remain was given its own layer, or theme, in ArcMap: Fauna; FBR; tools; debitage; and projectile points. The layers that were created were either digitized as point or polygon data types depending on their visual representation. This process was time consuming as close to 12,500 archaeological remains were digitized into the GIS.

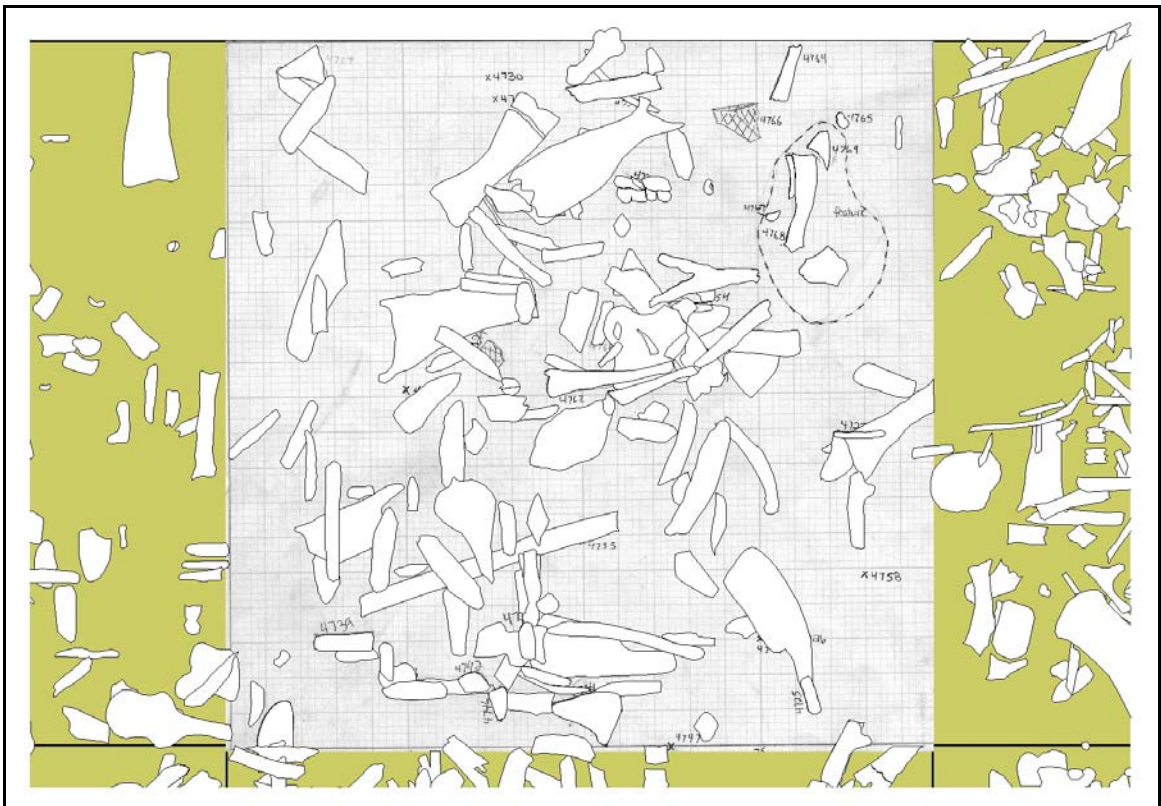


Figure 3.4: An example of the digitizing process. The level graph was placed in its correct spatial location and the remains traced over to create the shapefiles used in the spatial analysis.

During the digitizing process, the unique field number of each remain was entered into its attribute table. The catalogue number the archaeological remain was assigned during the processing phase (mentioned in a laboratory section above), was also entered into the GIS. This was done by manually linking the field and catalogue numbers from the Access databases. With this step complete, each remain had its field and catalogue number connected with its digitized remain. Entering this data into the GIS in this way allowed for error checking in the data entry, such as mis-typing the field or catalogue numbers, or entering in the wrong coordinates. Missing entries were entered and multiple entries were eliminated. Moreover, the catalogue number was used as the unique identifier of each remain or group of remains in the case of sieved unidentifiable pieces from the same level of a unit. The Access databases and digitized GIS data were linked using this identifier.

Calculating Centroids

Digitizing the remains as polygons was important because it gave a realistic visual representation of a site. The spatial analyses used in this thesis required point data, however. In cases where the archaeological remains were digitized as polygons, including the fauna and FBR at Fincastle, the centre of each polygon was calculated in order to display them as point data. To do this, the coordinates of a remain were calculated within its UTM zone, such as North American Datum 1927, UTM 12N. Two new fields were then created in the attribute table in order to display the polygons as point data: XCentroid and YCentroid fields. Using the 'Calculate Geometry' function in the attribute table, the XCentroid and the YCentroid were automatically but separately calculated. Once this was accomplished, the XY point data was displayed in ArcMap,

maintaining all of the attributes from the polygon shapefiles. Figures 3.5 and 3.6 are provided as an example to show how this process worked.

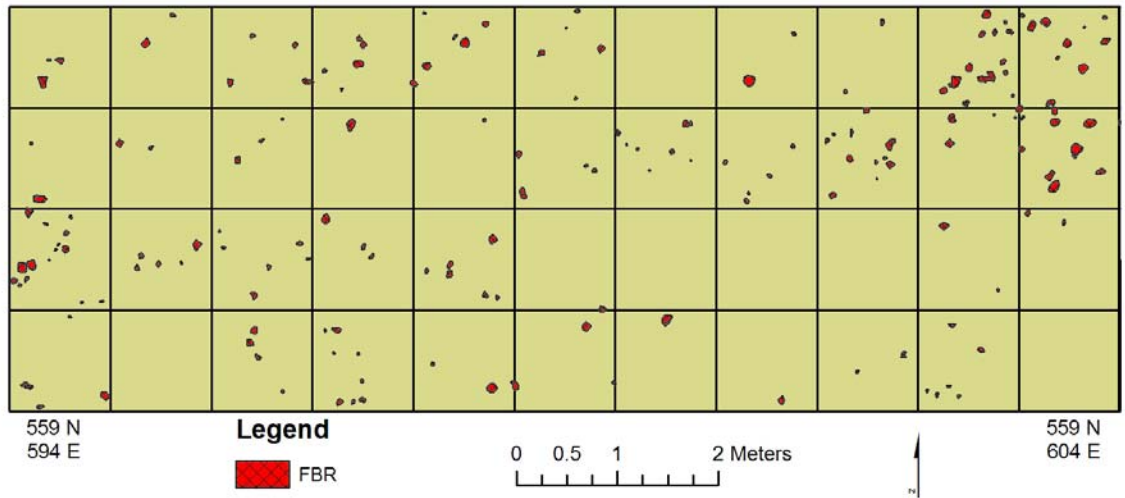


Figure 3.5: Portion of the East Block showing the FBR as polygons.

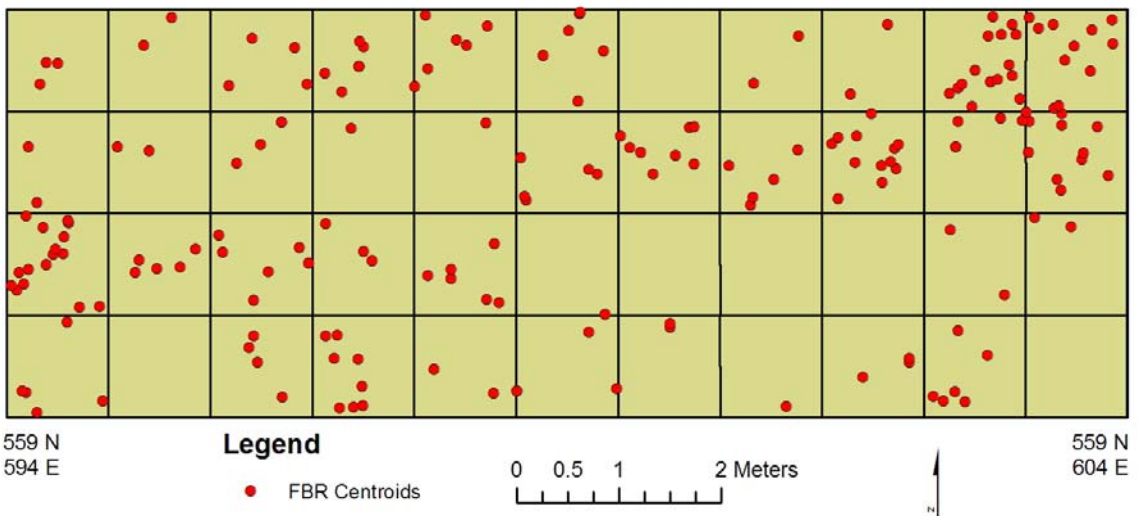


Figure 3.6: Calculated centroids of the FBR polygons in Figure 3.5.

An alternative to this procedure was to import the entire database and display XY data from there. This was able to be done for this project because the required UTM coordinates (spatial data) were entered into the Access databases. This XY data was not

automatically saved as a shapefile though, so in order to avoid re-displaying the data every time the GIS is opened, it needed to be exported as a shapefile. This shapefile only had to be loaded once into the saved GIS project.

It was still beneficial, however, to calculate the centroids of each remain in order to compare them with the imported database coordinates. This allowed for the checking of spatial errors. If the coordinates of an archaeological remain were erroneously entered into the database, the calculated centroid would not be in the same location as the imported coordinates from the database. These errors were corrected in the database by looking up the artefact in the records. Corrected information was re-imported into the GIS. This procedure was done for all the digitized remains excavated at the Fincastle Site (Figure 3.7).

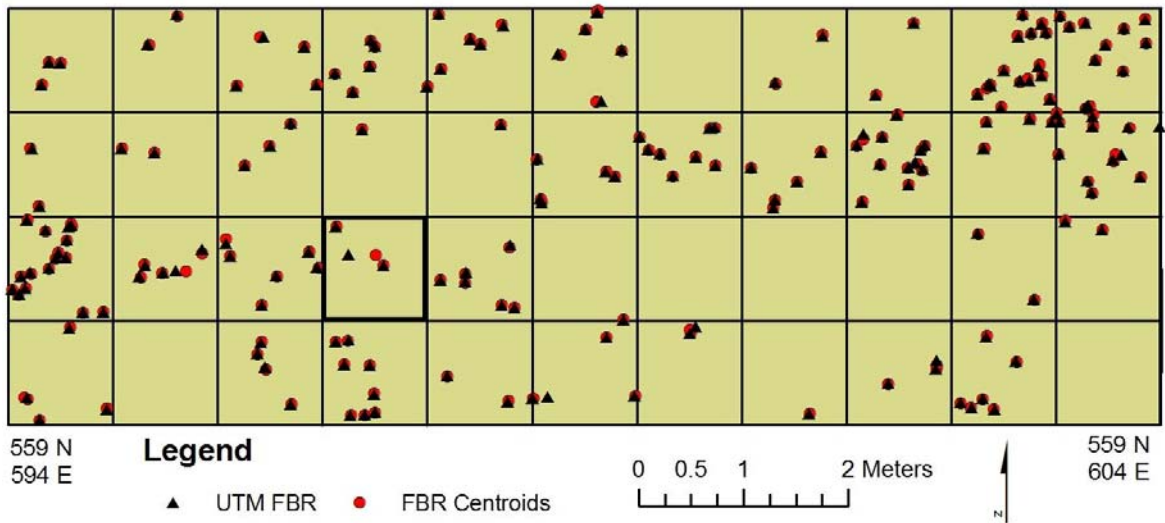


Figure 3.7: Comparison between the UTM coordinates of the FBR and the calculated centroids. The triangles (UTM) covered the circles (centroids) if they had the exact same coordinates. If there was a difference between the UTM and the calculated centroid locations, a portion of the circle was visible. The unit with the thickened line had an error between the UTM coordinate and the calculated centroid. Other minor errors can also be seen in this image of the East Block.

Another benefit of importing the UTM coordinates from the database is that all of the attributes recorded during the processing and analysis stages are imported into the GIS as well. This eliminates the extra step of linking the tables with the polygons. Random UTM coordinates can also be generated for the archaeological remains recovered from the screen or found in secondary context, as was the case in the looted area of the site. Though these remains were not collected *in situ* they can still aid in the spatial interpretation of the site, especially since most of the remains are linked with a 1x1 m unit. Figure 3.8 displays the faunal remains found *in situ*. In four units, it is evident that looting took place. The artefacts collected in the East Block after the looting were randomly plotted into the four units left unexcavated between 2004 and 2007 (Figure 3.9). Though the remains cannot be visually represented as polygons, they can be used in the spatial analysis of the site.

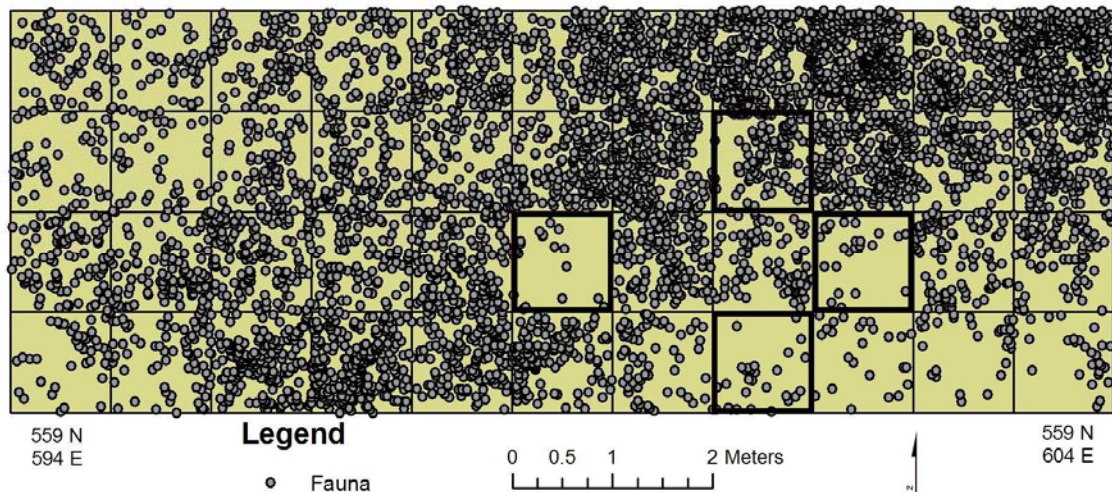


Figure 3.8: Portion of the East Block grid showing the UTM location of the *in situ* faunal remains. Units highlighted with thickened lines were looted after the 2004 field season.

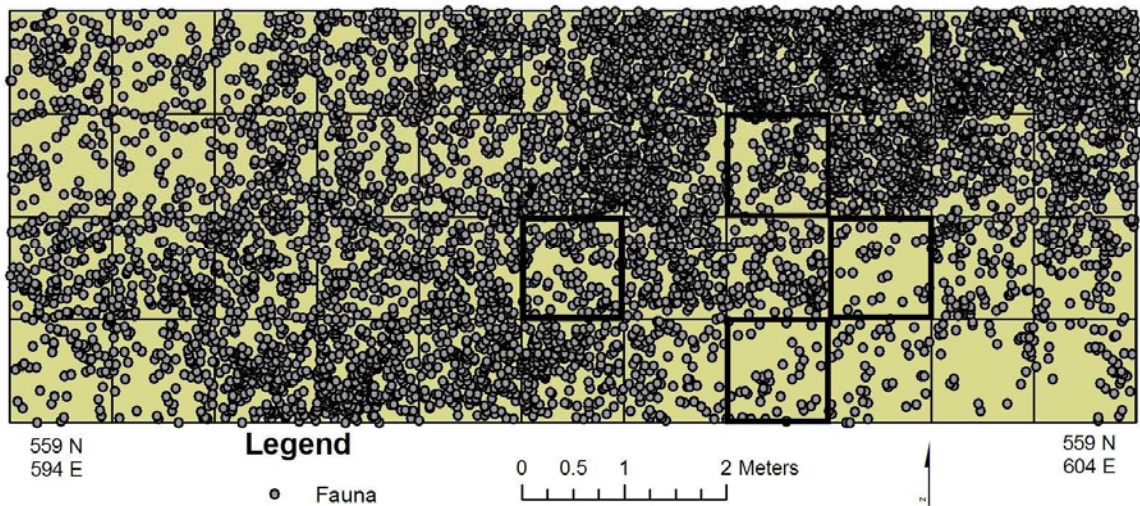


Figure 3.9: Portion of the East Block with the *in situ* and randomly plotted fauna that were collected after the looting took place. While the distribution of remains within the looted units is not exact, they now can be included in the spatial analysis. Note: The three units in the bottom right-hand corner were not looted; the *in situ* distribution in that part of the East Block was sparser.

Calculating Spatial Statistics in a GIS

It is important to spatially analyze an archaeological site in order to determine if and where cultural patterns exist. An abundance of archaeological remains at a site, such as at Fincastle, can make visual interpretation difficult. Applying spatial analytical techniques to the remains can be helpful in determining where cultural activities were more pronounced, something that may not be evident when in the field or when analyzing the remains in the laboratory.

The basic quadrat analysis and the nearest neighbour statistical tests were chosen because they are often used in an archaeological context (see Chapter 2). The Moran's I, Getis-Ord General G_i^* , Ripley's K and the kernel density estimation tests are rarely used by archaeologists because of their complexity, however, because they are available in ArcGIS, these tests were used and studied as well. The spatial analyses were carried out

based on the assumption that the archaeological remains were in primary context and belong to a single occupation event at the Fincastle Site. Although the faunal remains constitute the majority of the archaeological remains recovered, it was also important to analyze them in conjunction with the FBR and lithic remains in order to gain an understanding of how different cultural activities were carried out at the site.

Since all of the archaeological material entered into the GIS had spatial coordinates in the form of point data, calculating the statistics was relatively easy. Using the ArcMap spatial statistic toolbox, the nearest neighbour, Moran's I, Getis-Ord General G_i^* and Ripley's K function were used to analyze the spatial distribution of the remains. These statistical calculations either confirm or reject the presence of clustering in an archaeological assemblage. Since the nearest neighbour statistic does not take into account direction or distance, the Moran's I, Getis-Ord General G_i^* and Ripley's K methods were used to test this aspect. To maintain consistency, the Moran's I and Getis-Ord General G_i^* statistical tests were set to a distance of 0.25 m to measure the number of points that fell within this specified area. This matches the intervals used in quadrat analysis and kernel density estimation (see below). The Ripley's K statistic was set to measure ten distance bands starting at 0.05 m up to a distance of 0.5 m, with the 0.25 m distance used for quadrat analysis and kernel density estimation falling in the middle of the distance bands. This allowed for comparisons between methods.

Quadrat analysis and the kernel density estimation were used to analyze of the archaeological remains that had enough data and variability in the number of remains per square meter to work with. These methods give a visual output that can be used to detect observable clustering.

Using ArcGIS, each archaeological remain was plotted and its spatial location displayed on a distribution map. The results from the spatial statistical methods were either output as a visual map or in numerical format. The results were presented in table format to determine the degree of clustering each type of remain exhibited. The spatial relationships between the different archaeological remains were then examined. Though cultural relationships can be inferred using the results from this type of spatial analysis, they were not fully investigated in this study as the focus of this thesis was to assess the value of using a GIS in an archaeological setting.

Summary

The methodology outlined in this chapter shows that in order to carry out a detailed spatial analysis of a site, a great deal of data must be collected throughout the project because all aspects (field methodology, laboratory analysis, etc.) are connected. If meticulous records are not kept while in the field, linking the laboratory analysis with the spatial analysis is much more difficult. The more information that can be recorded in the field the stronger the spatial analysis.

From the very beginning, the field methodology was set up to incorporate the use of a GIS as an analytical tool. This included obtaining a large enough sample to culturally interpret the site. Through the detailed excavation techniques, which involved excavating 1x1 m units in a checkerboard pattern, following 5cm levels, the recording of all archaeological material and the drawing of *in situ* material, an analysis using a GIS was possible. These techniques allowed for the collection of a large quantity of information for each of the fauna, FBR and lithic remains.

While in the field, the stratigraphy was also drawn and examined. The context of the remains excavated at the Fincastle Site confirms it was only occupied once. The entire bone bed was situated on top of glacial lacustrine clays, buried under aeolian sands that were stabilized by soil formation processes. Five radiocarbon dates place the site in the Late Middle Prehistoric Period at 2,500 BP.

All of the remains collected in the field were brought back to the laboratory for further processing and analysis. Each type of remain (projectile points, lithic tools, debitage, FBR and fauna) were processed and analyzed according to the frequently used guidelines followed in the discipline of archaeology. This allowed for the creation of the Access databases that were used in the GIS to spatially analyze the site of Fincastle.

The GIS research started with the scanning in of all of the level graphs and spatially registering them to their proper coordinates. With this step complete, each type of remain was digitized into its own shapefile. Each individual remain was assigned its field number in order to be able to enter in its corresponding catalogue number, which was assigned during the processing phase. The catalogue number was used to link the GIS shapefiles to the Access databases.

Since the spatial statistical techniques require point data, the polygon shapefiles were not usable. The UTM coordinates of the remains that were digitized as polygons (lithic tools, FBR and fauna) were imported into ArcGIS as point data and saved as new shapefiles. The calculated centroids of the polygon data were compared to the UTM coordinated to check for any errors that occurred during the excavation, recording, processing, and/or analyzing processes. Once the error checking was completed, the point plots were created and the spatial statistical methods were carried out on each type of

data to determine the degree of clustering that was present in the distribution. Chapter 4 examines and discusses the results from the point plots and the spatial statistical tests that were carried out on the archaeological remains collected from the Fincastle Bison Kill Site.

Chapter 4 – Spatial Analysis of the Fincastle Bison Kill Site (DIOx-5)

Introduction

As noted in Chapter 3, each archaeological remain was digitized into the GIS in order to carry out the spatial analysis. This part of the research began by looking at each type of remain separately. This chapter opens with the examination the lithic data, starting with the projectile points and lithic tools. Point plots were created for all areas of the site (the West Area, Test Pits and East Block) to observe where these remains were located spatially. Only the statistical methods with numerical outputs were carried out on these two types of remains due to the small amount of data associated with them. For the debitage, fire broken rock and fauna, point plots and all of the spatial statistical tests were carried out. Kooyman's (2006) boundary theory was also taken into consideration when interpreting the point plots in order to delimit different areas of cultural activities, such as hearths, boiling pits, tool manufacture and primary and secondary butchering areas. Once the individual analyses were complete, certain types of remains were studied in conjunction with each other to gain a better understanding of the cultural activities at the site of Fincastle. The ability of the GIS to handle archaeological data, as well as calculate statistics on the remains, was evaluated throughout this process.

Spatial Analysis

Projectile Points

Though the analysis concentrates on the East Block, projectile points were found in all three areas of the site. The projectiles from the West Area, where the original looting took place, may not be represent the actual number of points left at the site 2,500

years ago (Figure 4.1), however; twelve projectile points were unearthed in the West Area, averaging 0.6 per square meter. The Test Pits yielded five projectile points, averaging 0.83 per square meter (Figure 4.2), leaving one to wonder whether the looter removed only a few from the West Area, or if the West Area was once much richer in material. The majority of the projectile points were unearthed in the East Block, where the intact bone bed was found. Eighty-eight projectile points were recovered, averaging 1.09 per square meter. Of these, 47 were complete and 41 were fragments.

The East Block distribution map shows where the projectile points were found (Figure 4.3). It is clear that the projectile points were scattered across the block, although some degree of clustering is evident.

To test this visual interpretation, the nearest neighbour, Moran's I, Getis-Ord General G_i and Ripley's K statistical tests were carried out despite the small sample size. The results (Table 4.1), weakly suggest a clustered distribution.

The fact that the nearest neighbour ratio is less than one suggests a clustered distribution, but since the value is approaching one, it is not tightly clustered. This could be due to the low number of projectile points recovered or because the distribution may be random. The nearest neighbour z-score of -1.98 (less than -1.96) also supports a clustered distribution. The significance value from this method, 0.05, denotes a 5% chance that this pattern could be the result of random chance.

The positive Moran's I value also confirms a clustered distribution of the projectile points. Again, however, the very small value indicates that the clustering within the distribution is not strong. Furthermore, the significance value is 10% for this statistic, meaning there is a chance this pattern is random. The calculated Getis-Ord

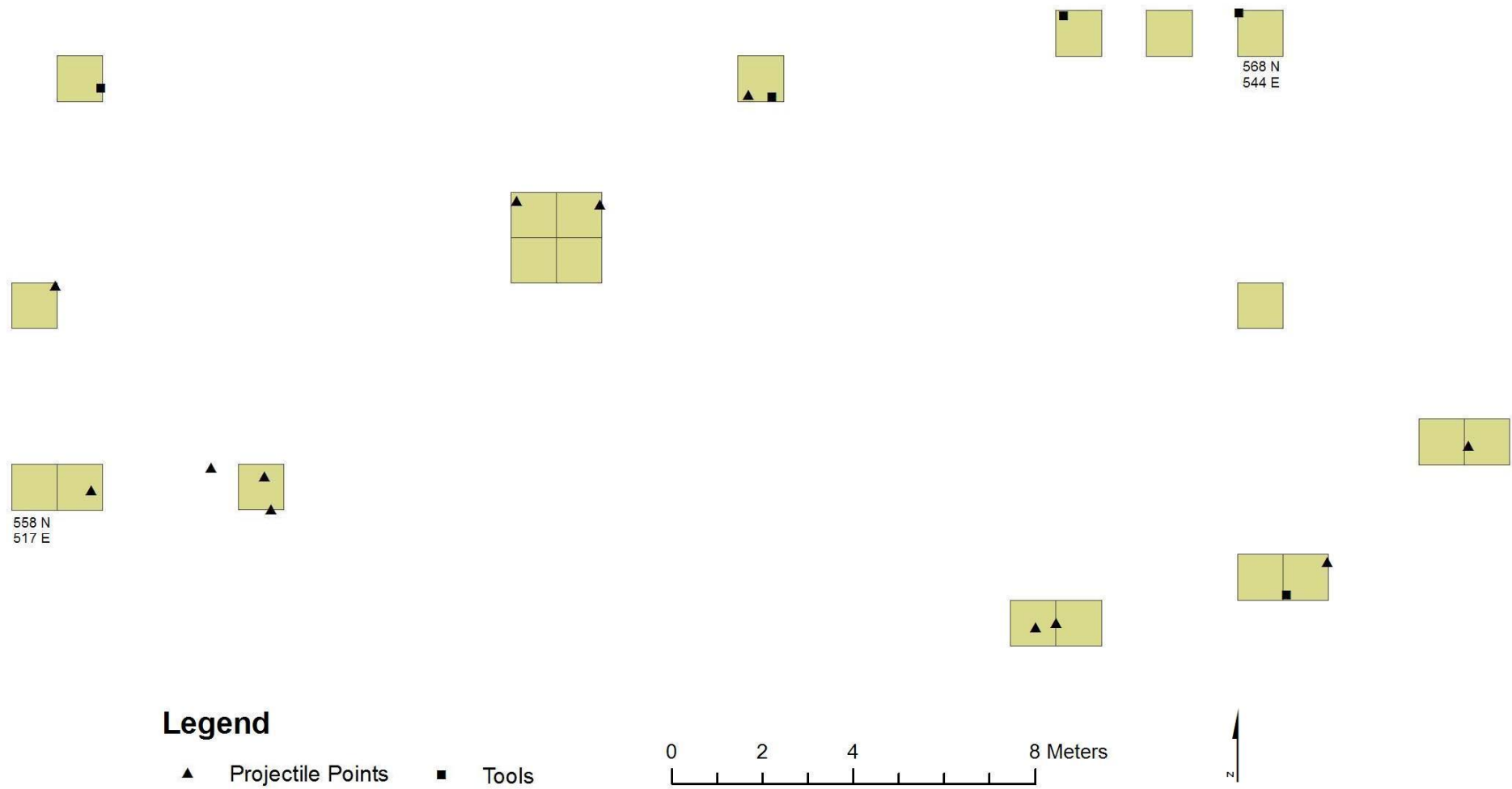


Figure 4.1: An overview of the location of all the projectile points and lithic tools found in the West Area of the site.

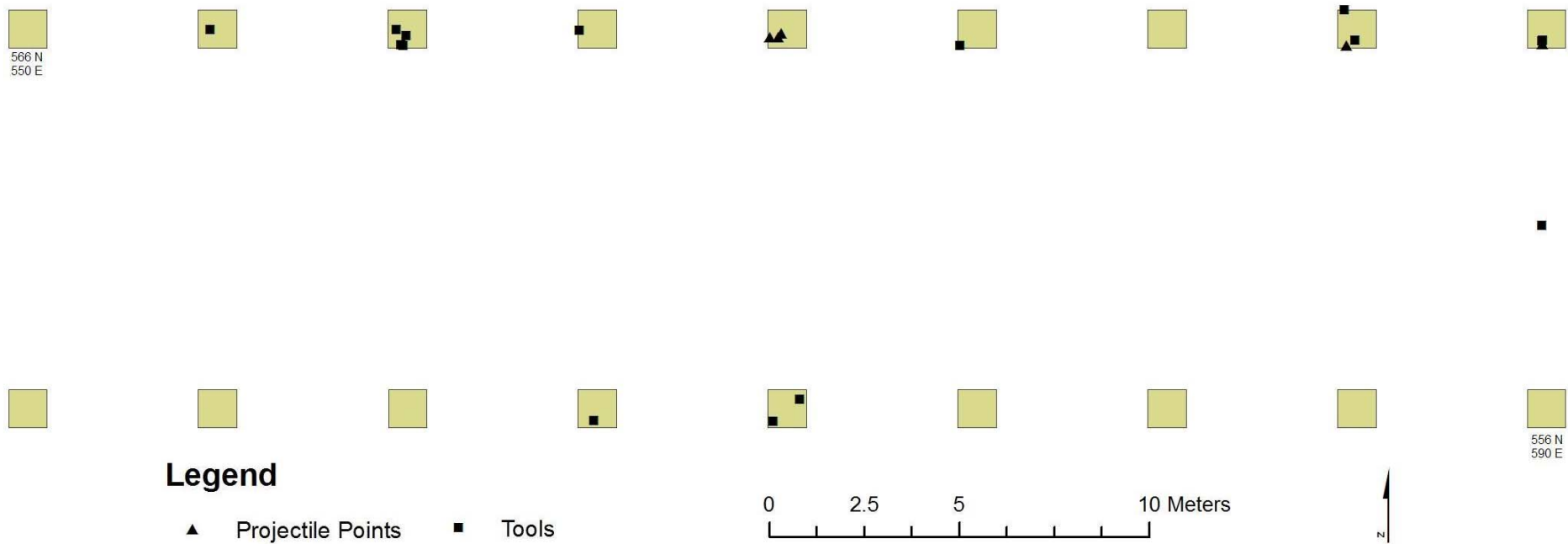


Figure 4.2: An overview of the location of all the projectile points and lithic tools found in the Test Pits.

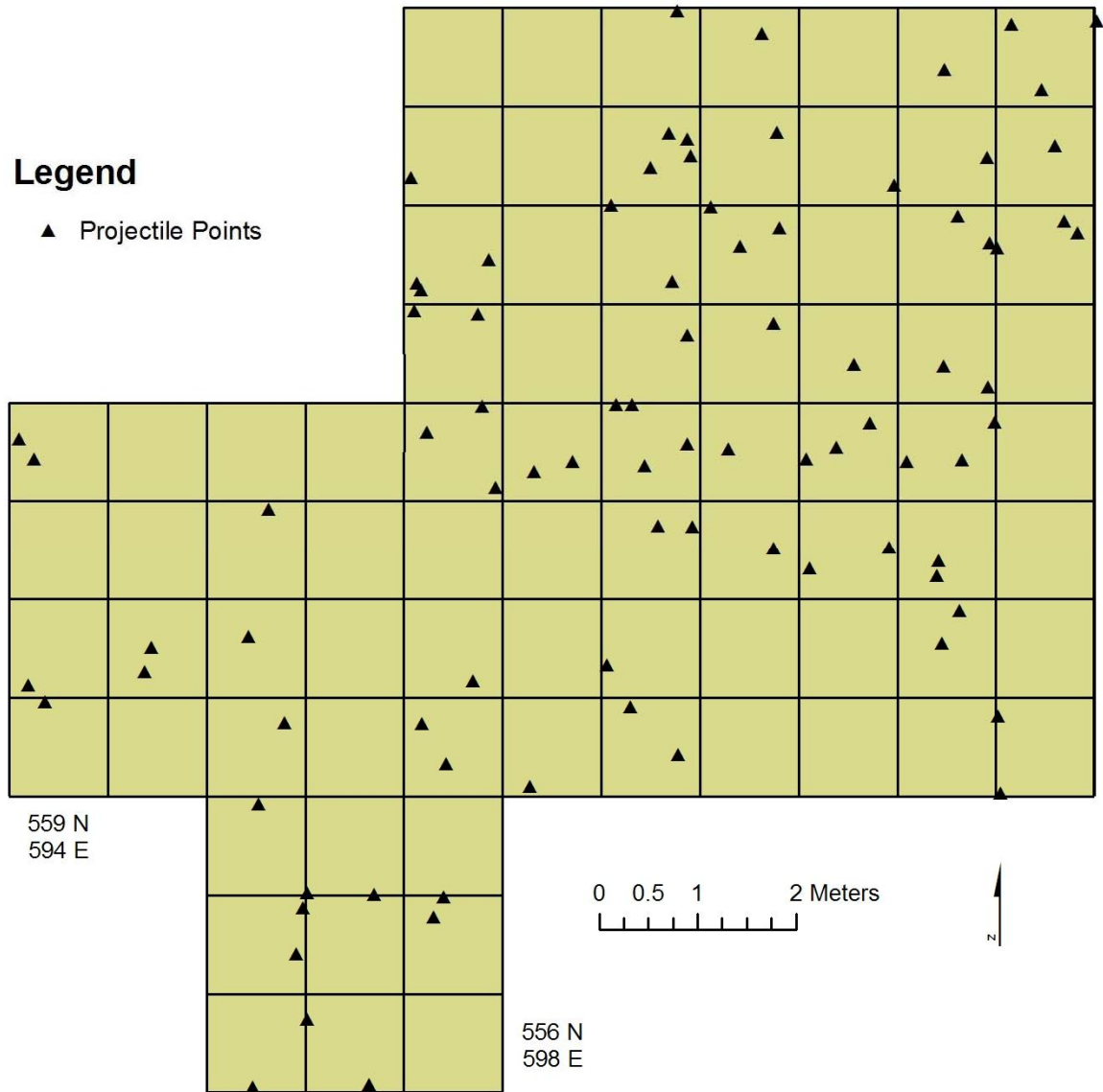


Figure 4.3: An overview of the location of all the projectile points found the East Block.

General G_i statistic confirms the weak clustering within the projectile points. This can be seen by the small index, as well as the low, but positive z -score.

In order for the Ripley's K statistical test to support a clustered distribution, $L(d)$ must be greater than zero. As seen in Table 4.2, the results from this test show a stronger

spatial relationship as the distance bands increase. This is not surprising considering that the larger the area, the more neighbours a point will have.

Table 4.1: Results from the nearest neighbour, Moran's I and Getis-Ord General G_i spatial statistical tests carried out on the projectile point data from the East Block.

	Ratio/Index	z-score	Significance Value
Nearest Neighbour	0.875	-1.98	0.05
Moran's I	0.002	1.65	0.10
Getis-Ord General G_i	0.330	1.96	0.05

Table 4.2: Results from the Ripley's K statistical test carried out on the projectile point data from the East Block.

Distance (m)	L(d)
0.05	0.537
0.10	0.588
0.15	0.646
0.20	0.699
0.25	0.773
0.30	0.838
0.35	0.892
0.40	1.010
0.45	1.070
0.50	1.109

Lithic Tools

The lithic tools include both large (anvils, hammerstones, choppers etc.) and small (scrapers, knives, retouched flakes, etc) tools. They were found in all three areas of the site, though most came from the East Block. In the West Area, five tools were recovered (see Figure 4.1), averaging 0.25 per square meter. The Test Pits yielded 16 tools (see Figure 4.2) (2.67 per square meter). The excavations in the East Block unearthed 94 tools, averaging 1.16 per square meter. Based on the distribution of the lithic tools in the

East Block, as seen in Figure 4.4, it is apparent that the majority are located in the northern extension.

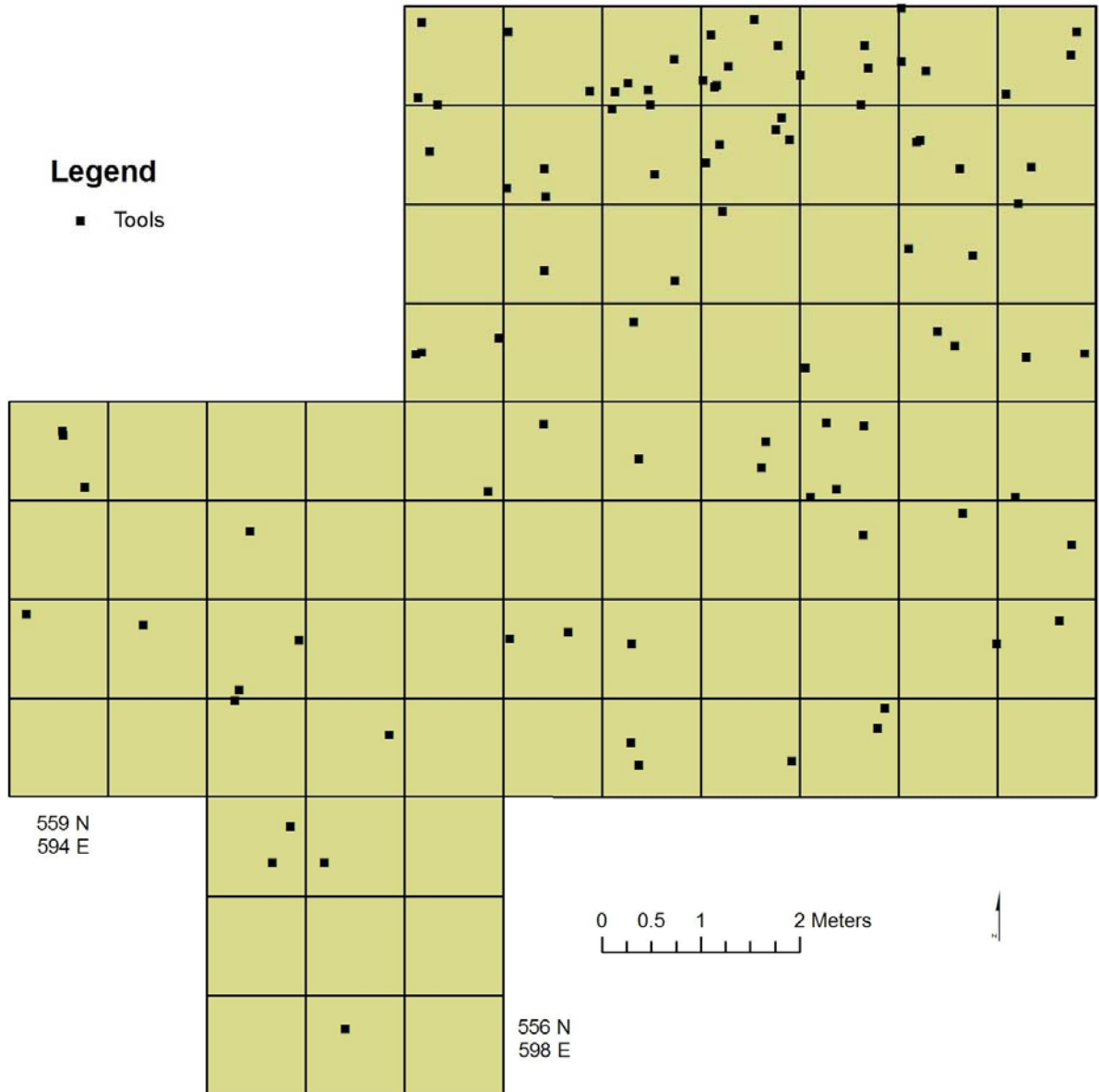


Figure 4.4: An overview of the location of all the lithic tools (excluding the projectile points) found in the East Block.

The spatial statistical tests (Tables 4.3 and 4.4) noted a clustered distribution, though, like the projectile points, it is not a strong relationship because of the limited

number of artefacts. Although the nearest neighbour ratio is approaching one (a random distribution), it is slightly smaller than the ratio calculated for the projectile points, meaning there is a stronger clustered distribution. The Moran's I statistical result is significantly larger than the result from the projectile points, which also supports a stronger spatial relationship. Finally, the Getis-Ord General G_i statistic also shows that the distribution of the lithic tools is more clustered than the projectile points. All three statistical tests carried out had a significance value of 0.01.

Table 4.3: Results from the nearest neighbour, Moran's I and Getis-Ord General G_i spatial statistical tests carried out on the lithic tool data from the East Block.

	Ratio/Index	z-score	Significance Value
Nearest Neighbour	0.839	-2.58	0.01
Moran's I	0.013	2.58	0.01
Getis-Ord General G_i	0.360	2.58	0.01

Table 4.4: Results from the Ripley's K statistical test carried out on the lithic tool data from the East Block.

Distance (m)	L(d)
0.05	0.693
0.10	0.764
0.15	0.795
0.20	0.899
0.25	0.979
0.30	1.067
0.35	1.136
0.40	1.223
0.45	1.289
0.50	1.337

The Ripley's K statistic (Table 4.4) also followed the same trend as the projectile points; L(d) increased as the distance increased, although from the starting distance of 0.05 m, the spatial relationship was stronger. Though the lithic tool data were limited,

there was a stronger spatial relationship detected for these remains than for the projectile points likely because of the higher number of artefacts. The results from the spatial statistical tests confirm this.

Debitage

Thedebitage was the most abundant lithic remain found during the excavations. In the West Area, 285 pieces were found, averaging of 14.25 per square meter (Figure 4.5). In the Test Pits, 288 pieces were found, equating to an impressive average of 48 per square meter (Figure 4.6).

There were 2,669 pieces ofdebitage recovered from the East Block (32.51 per square meter). Most pieces were collected from the sieve because of their small size (only 471 pieces were found in primary context), however, the detailed excavation methodology (see Chapter 3) allowed for the random plotting these artefacts within 1x1 m unit they came from so they could be included in this analysis. The plots show the calculated spatial locations of the sievedebitage and the *in situ*debitage. Valuable spatial relationships could be ascertained by running these data through statistical tests, as well as analyzing the density maps. Figure 4.7 shows the location ofdebitage in the East Block. It is clear that the highest concentration ofdebitage is in the northern extension.

Although there is a slight difference in the statistical results, the nearest neighbour, Getis-Ord General G_i and Ripley's K statistical outputs were similar (Tables 4.5 and 4.6). The *in situ*debitage and all of thedebitage together display a clustered distribution.

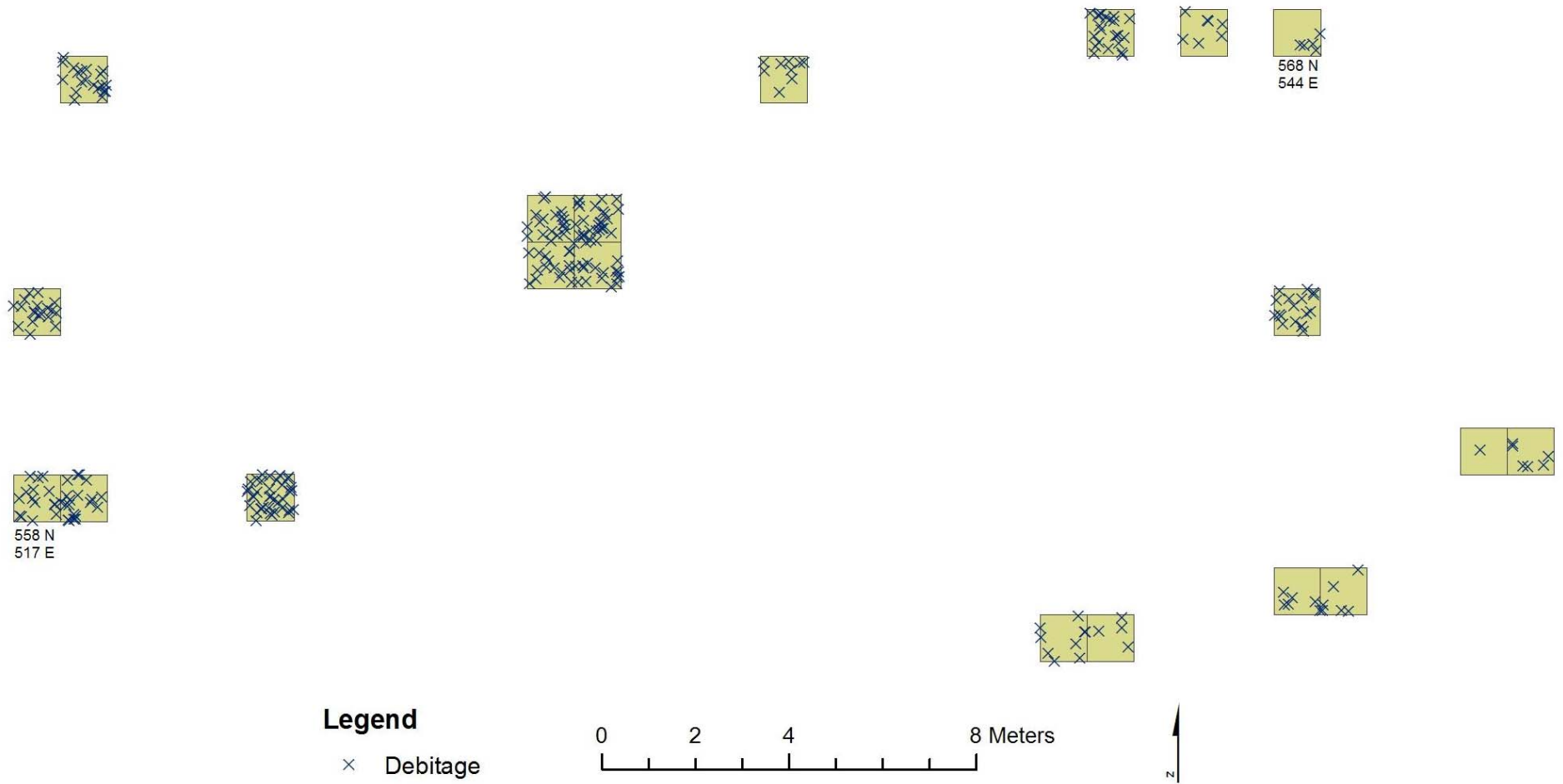


Figure 4.5: An overview of the location of all the debitage found in the West Area of the site.

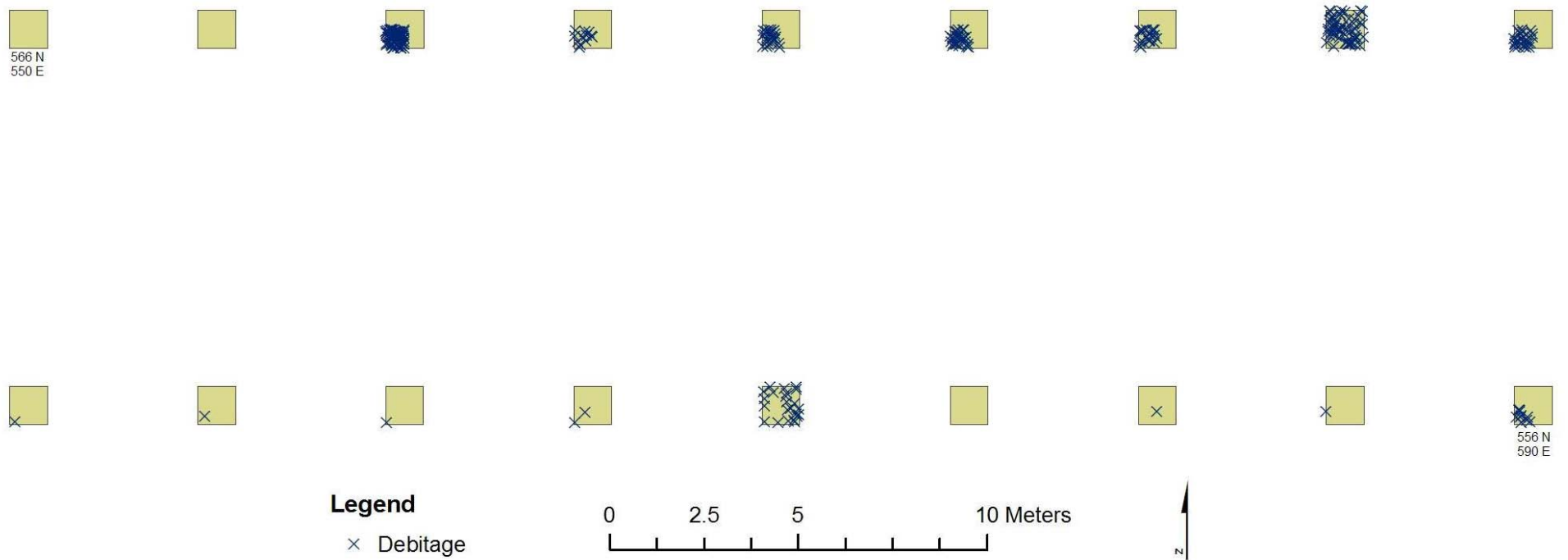


Figure 4.6: An overview of the location of all the debris found in the Test Pits.

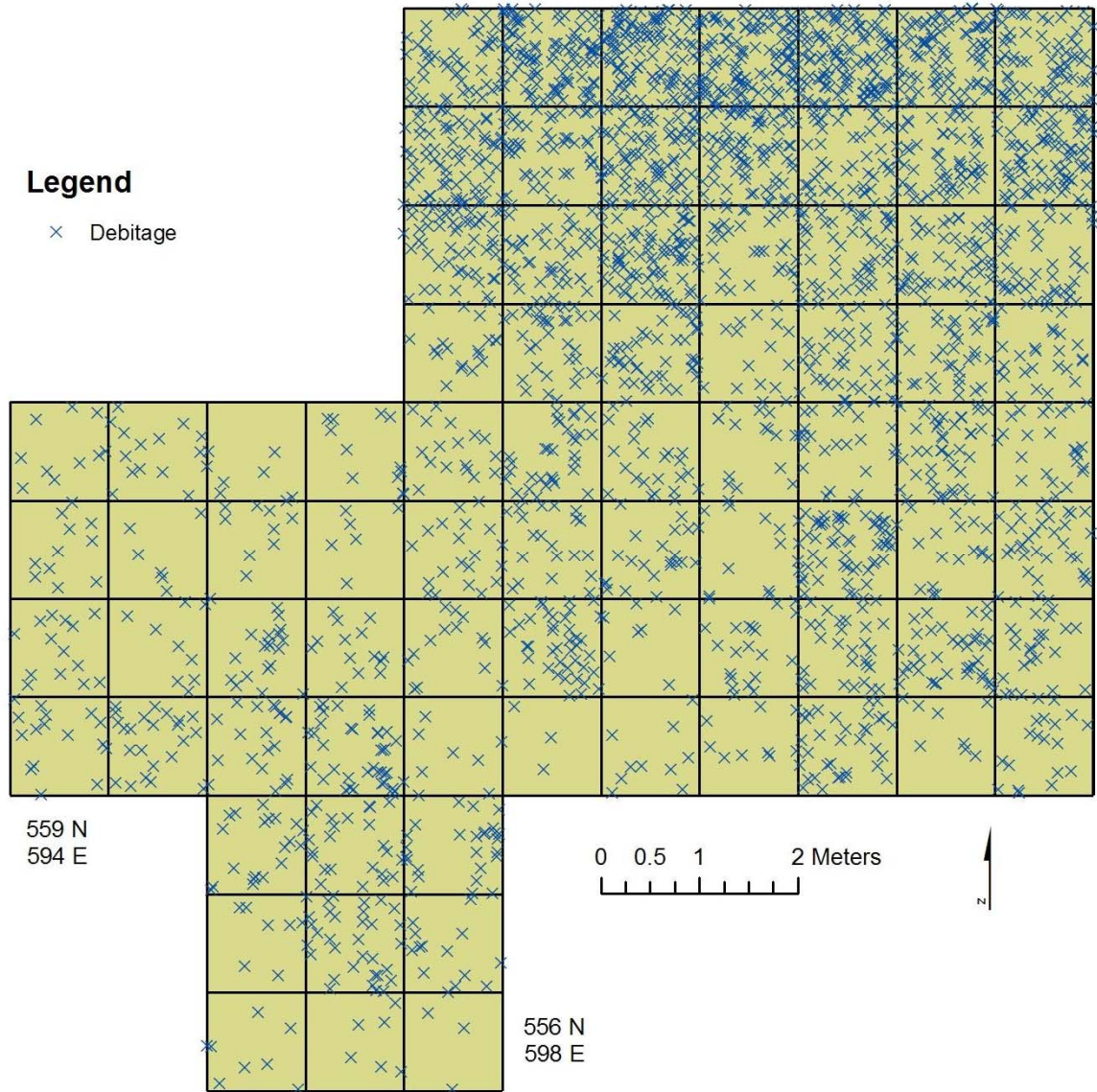


Figure 4.7: An overview of the location of all the debitage found in the East Block.

The nearest neighbour results were very similar. Based on the significance values calculated, there is less than a 1% chance that this spatial pattern is the result of random chance for either group. The Moran's I statistic also indicated a weakly clustered distribution for each, but it is even less clustered for the *in situ* debitage due to the lower number of data points. The calculated significance values from the Moran's I test also

affirm the clustered spatial pattern. The Getis-Ord General G_i index and the calculated significance values verify that the distribution between the two groups is similar.

Table 4.5: Results from the nearest neighbour, Moran's I and Getis-Ord General G_i spatial statistical tests carried out on the debitage data from the East Block.

All Debitage	Ratio/Index	z-score	Significance Value
Nearest Neighbour	0.763	-2.58	0.01
Moran's I	0.176	2.58	0.01
Getis-Ord General G_i	0.360	2.58	0.01
<i>In situ</i> Debitage			
<i>In situ</i> Debitage	Ratio/Index	z-score	Significance Value
Nearest Neighbour	0.782	-2.58	0.01
Moran's I	0.041	2.58	0.01
Getis-Ord General G_i	0.350	2.58	0.01

Table 4.6: Results from the Ripley's K statistical test carried out on the lithic tool data from the East Block.

All Debitage		<i>In situ</i> Debitage	
Distance	L(d)	Distance	L(d)
0.05	0.719	0.05	0.726
0.10	0.788	0.10	0.792
0.15	0.858	0.15	0.856
0.20	0.926	0.20	0.921
0.25	0.996	0.25	0.988
0.30	1.065	0.30	1.052
0.35	1.137	0.35	1.124
0.40	1.208	0.40	1.194
0.45	1.280	0.45	1.265
0.50	1.350	0.50	1.328

The Ripley's K statistic (Table 4.6) shows that over the ten distance bands, similar results were calculated for both the *in situ* debitage and all debitage together. The results from the spatial statistics confirm that even though the majority of the debitage was spread over a 1x1 m resolution, the sieve debitage can provide valuable spatial information if recorded with some level of spatial context. As seen over the ten distance

bands that the Ripley's K method output, there is a small difference, but overall, the two groups exhibited the same pattern.

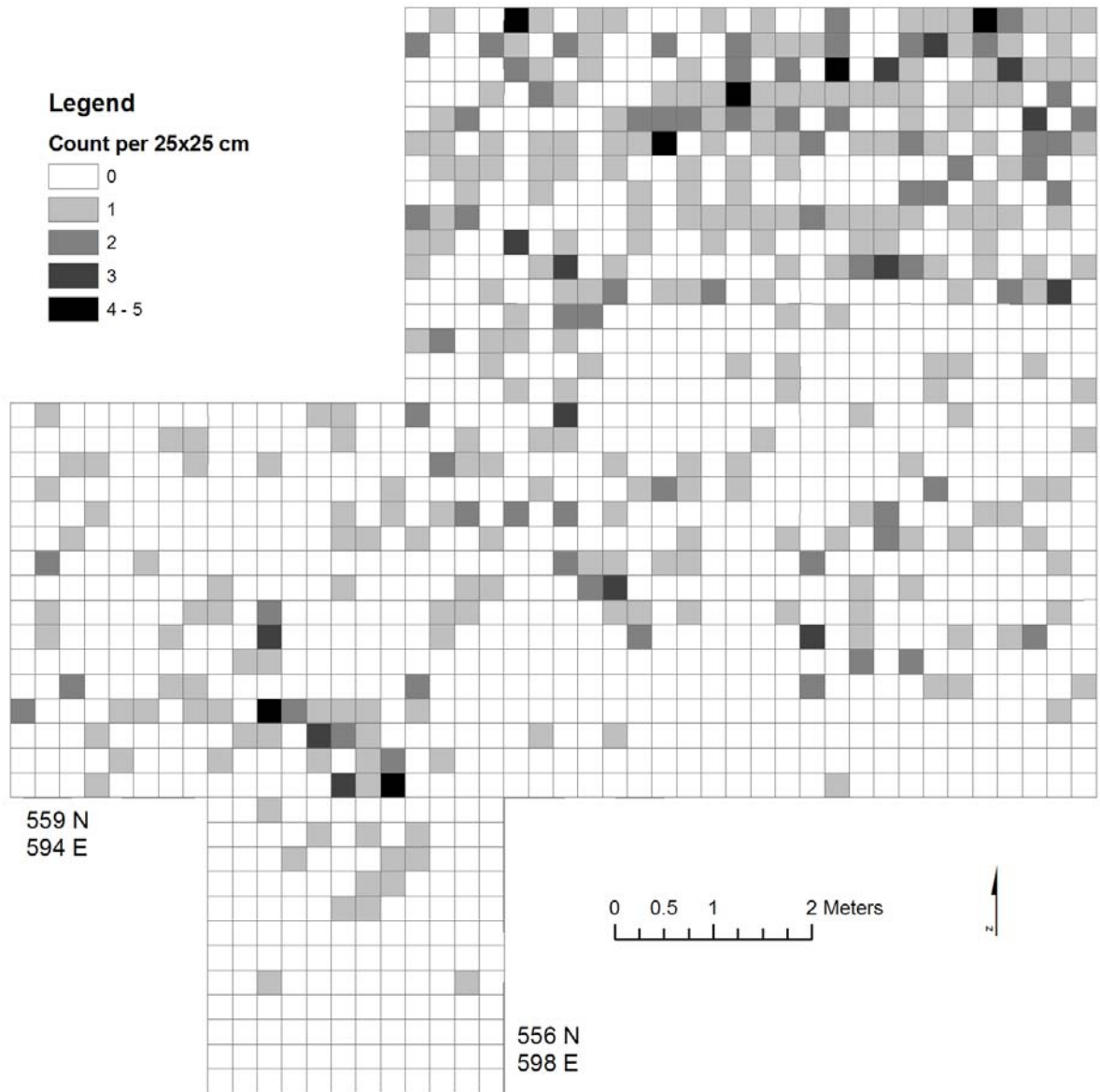


Figure 4.8: Quadrat analysis results for the *in situ* debitage from the East Block.

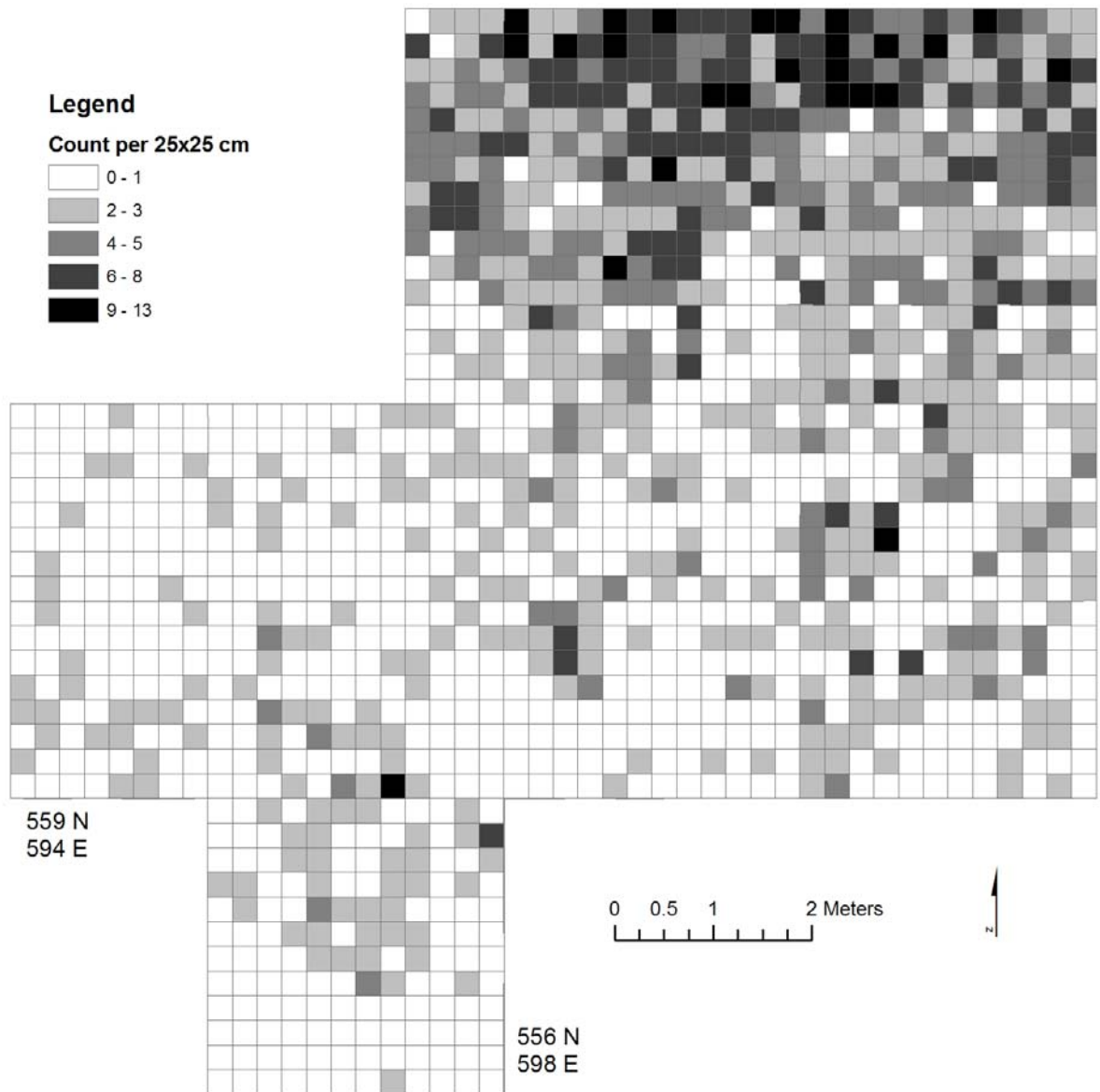


Figure 4.9: Quadrat analysis results for all the debitage from the East Block.

Quadrat analysis was also used to examine the spatial context of the debitage data. Figure 4.8 shows the number of *in situ* pieces of debitage per 25x25 cm quadrat. Based on this image of the East Block study area, it is clear that higher concentrations of debitage were found in the northern extension. This concentration was even more apparent when all of the debitage was used in the analysis (Figure 4.9). Kernel density

estimation (KDE) was calculated for all of the debitage in the East Block (Figure 4.10). Based on the outputted distribution, it is very clear where the pockets of highly concentrated debitage were found.

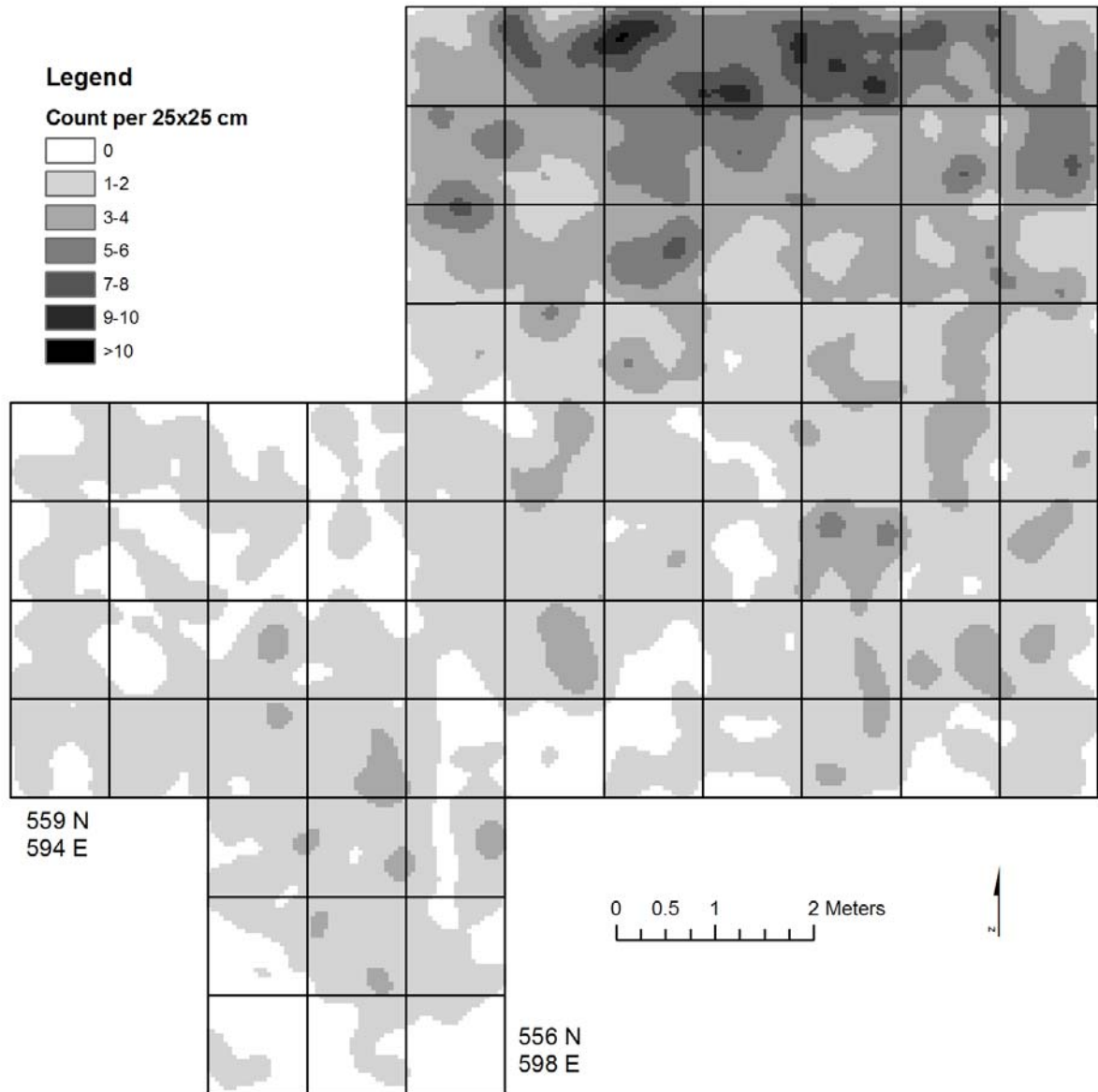


Figure 4.10: Kernel density estimation results for all of the debitage found in the East Block.

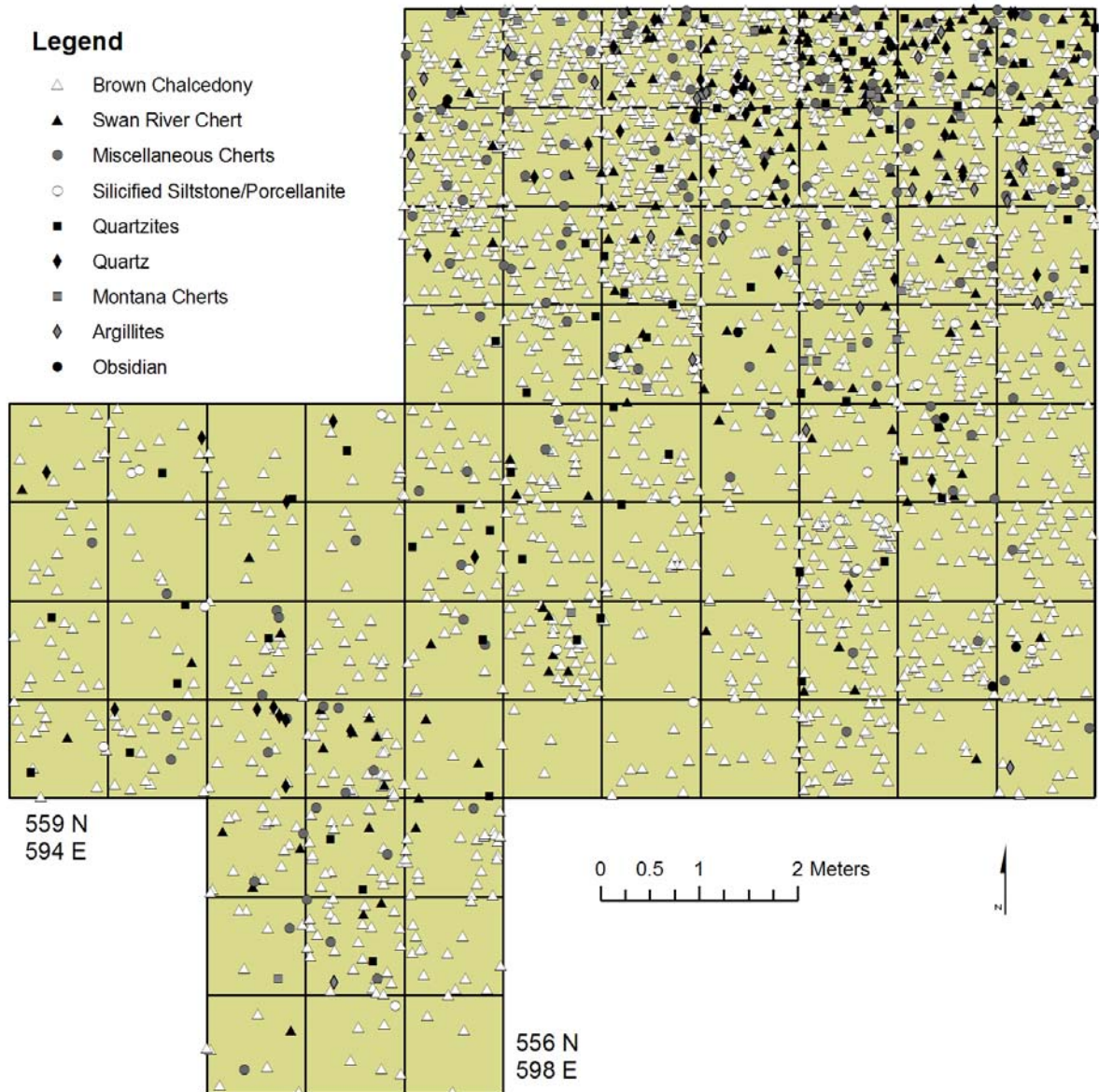


Figure 4.11: The location of all the debitage according to material type.

The large debitage data set allowed for the investigation of the spatial distribution of the material types, flake types, sizes and the relationship between the debitage and lithic tools. The dominant material used at the site was a brown chalcedony (possibly Knife River Flint). It represents 77% of the debitage recovered from the East Block, followed by Swan River (8%) and miscellaneous (6%) cherts. Other raw materials were

utilized around the site, but in limited quantities (9% of the total debitage). Figure 4.11 (above) shows the location of all the debitage according to material type, while Figure 4.12 displays where the brown chalcedony debitage was found. The high quantity of brown chalcedony is not surprising since most of the projectile points and tools were made from this material.

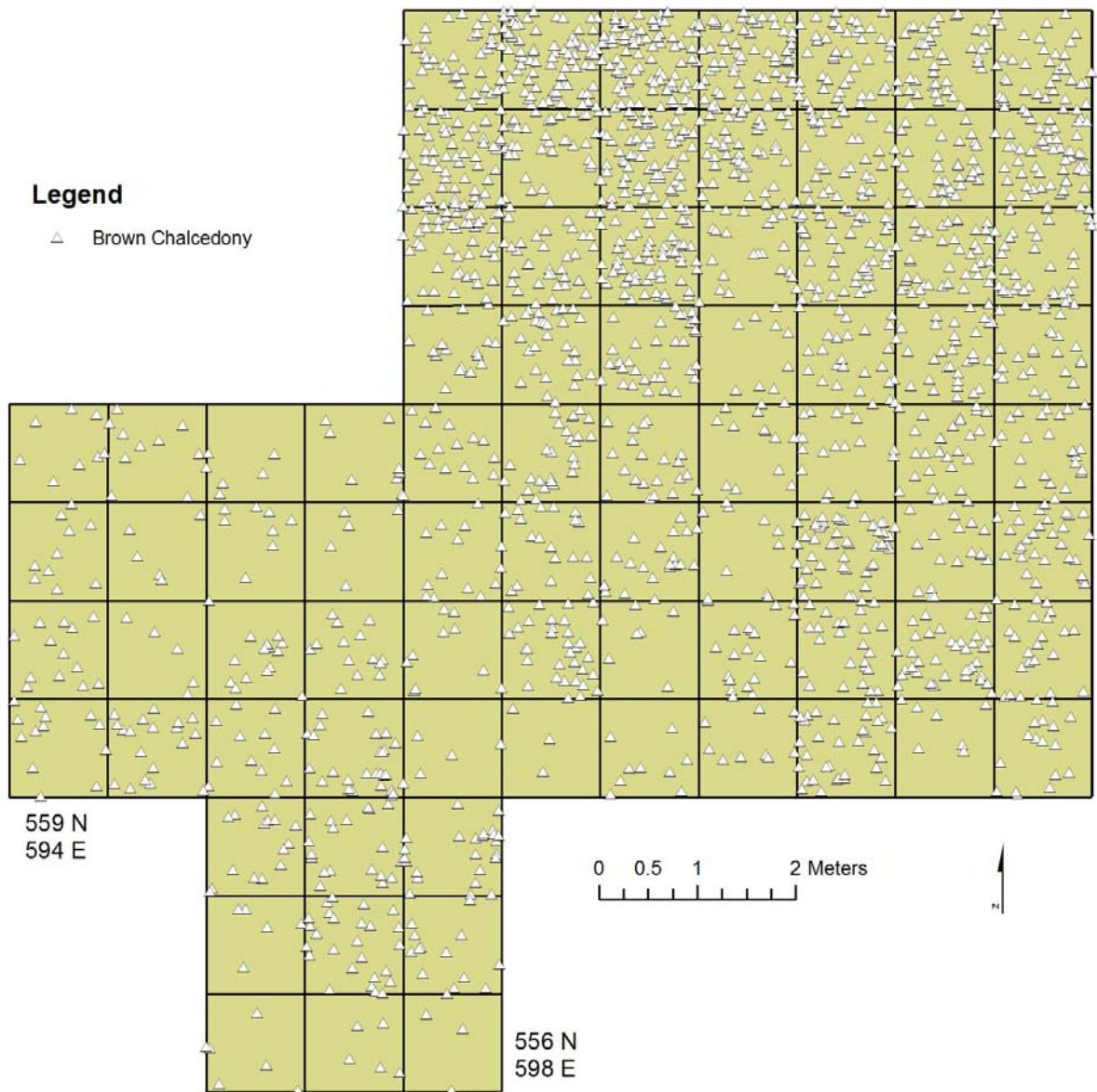


Figure 4.12: The location of all the brown chalcedony debitage.

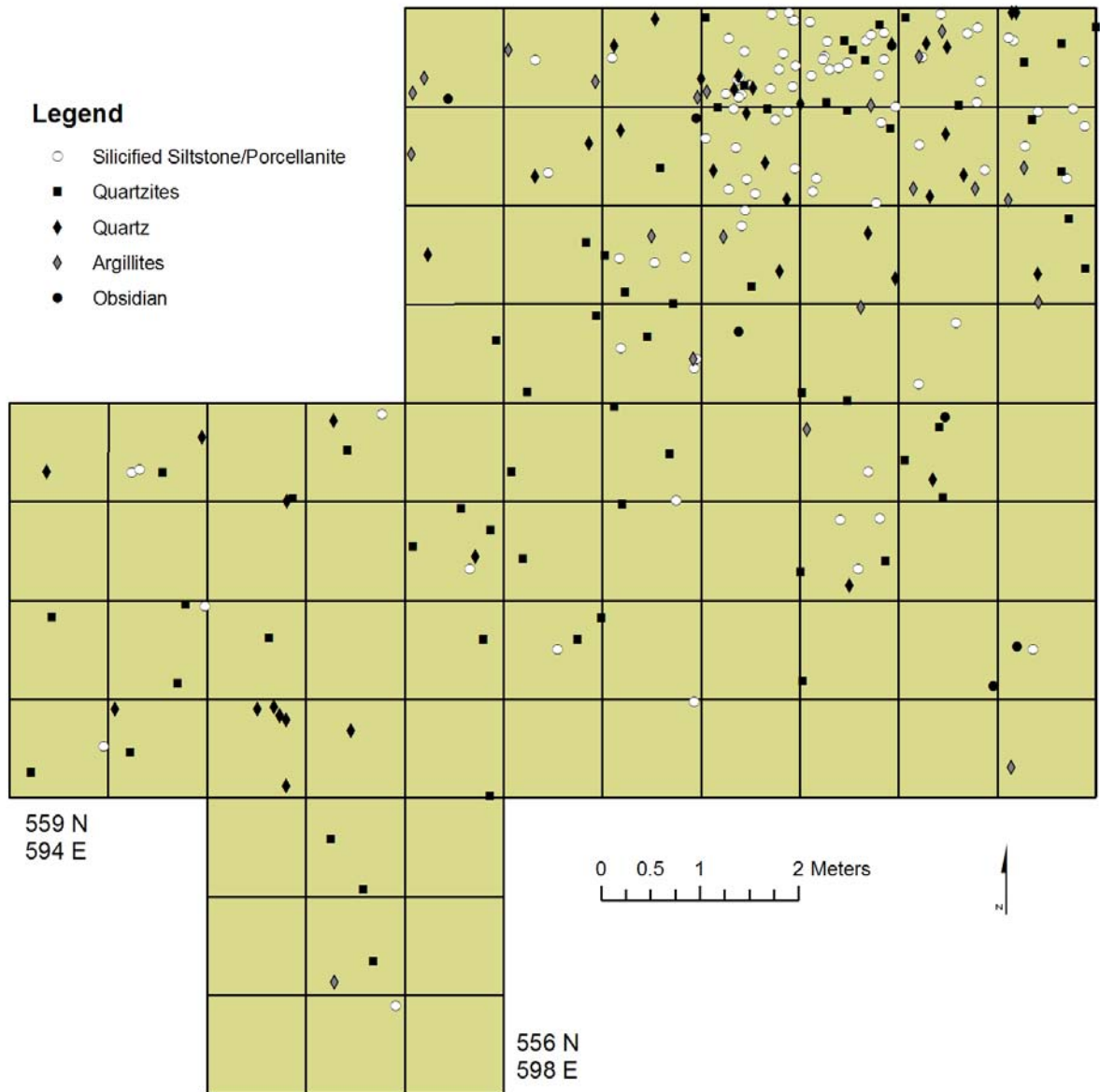


Figure 4.13: The location of the silicified siltstone/porcellanite, quartzite, quartz, argillite and obsidian debitage groups.

It is interesting to note that the other types of raw material (including quartz, quartzite, argillite and silicified siltstone/porcellanite) were predominantly located within the northern extension of excavation block (Figure 4.13), as were the Swan River,

Montana and miscellaneous chert groups (Figure 4.14). This distribution suggests that manufacturing and the re-sharpening of lithic tools took place at a higher rate in the northern extension when compared to the other areas of the East Block.

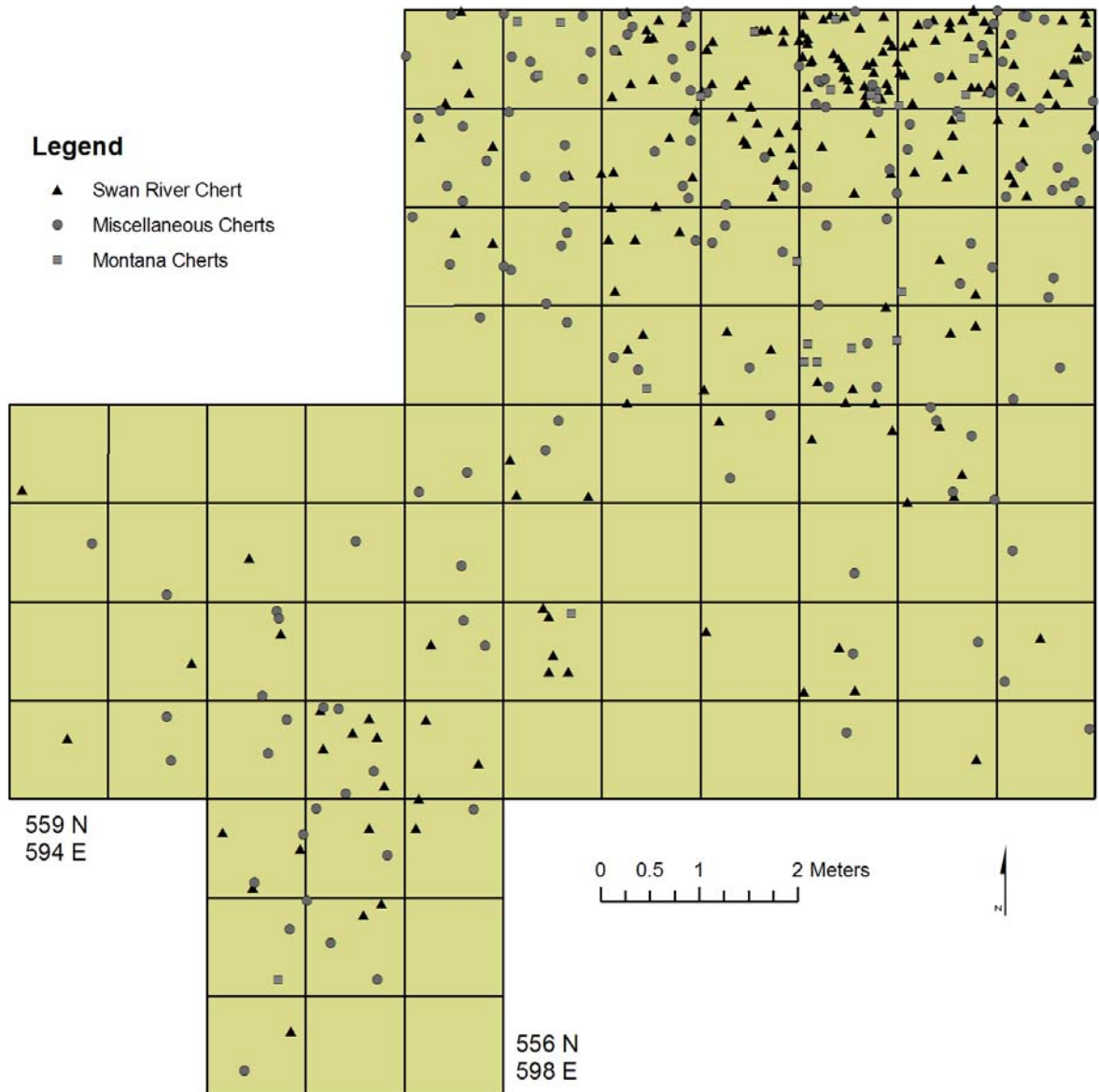


Figure 4.14: The location of the Swan River, miscellaneous and Montana chert debitage groups.

The reduction sequence of tool manufacture was studied using debitage attributes, such as the flake type and size. The amount of cortex present on a flake, for example, indicates the reduction stage (Andrefsky 2005: 103). The cortex of the raw material will be removed in order to use the interior of the stone for lithic tool production. Therefore, a dominance of flakes with cortex represents an earlier stage of lithic tool production than small flakes with no cortex. In ideal production situations, interior blanks will then be formed into lithic tools. The size of waste flakes produced from manufacture can assist in the reconstruction of the reduction sequence as well (Andrefsky 2005: 187).

A flake can be primary (>90% cortex present), secondary (some cortex present) or tertiary (no cortex present). From the distribution displayed in Figure 4.15, the majority of the debitage recovered from the excavations were tertiary flakes. They represent 68% of the debitage recovered from the East Block. Tertiary flakes can be the product of advanced core reduction, tool shaping, tool re-sharpening and tool use during butchering. Because primary and secondary flakes together represent only 4% of the debitage in the East Block (the remaining 28% were classified as shatter and flake fragments), minimal initial core reduction took place in this part of the site.

Moreover, as can be seen in Figure 4.16, only nine primary flakes were found and of these pieces, only one was brown chalcedony. It is, therefore, likely that brown chalcedony core preparation took place elsewhere. The rest were made from other cherts and quartzites, suggesting that local raw materials may have been utilized in the manufacturing of tools when needed. The secondary flakes were also separated out into material types (Figure 4.17). Eight of the nine raw material groups were represented. Brown chalcedony flakes were the dominant material type, but quartzite was also highly

represented, which also supports the hypothesis of local material acquisition. Though manufacturing activities took place across the East Block, they were more prevalent in the northern extension, evidenced by the higher numbers of pieces of debitage per square meter.

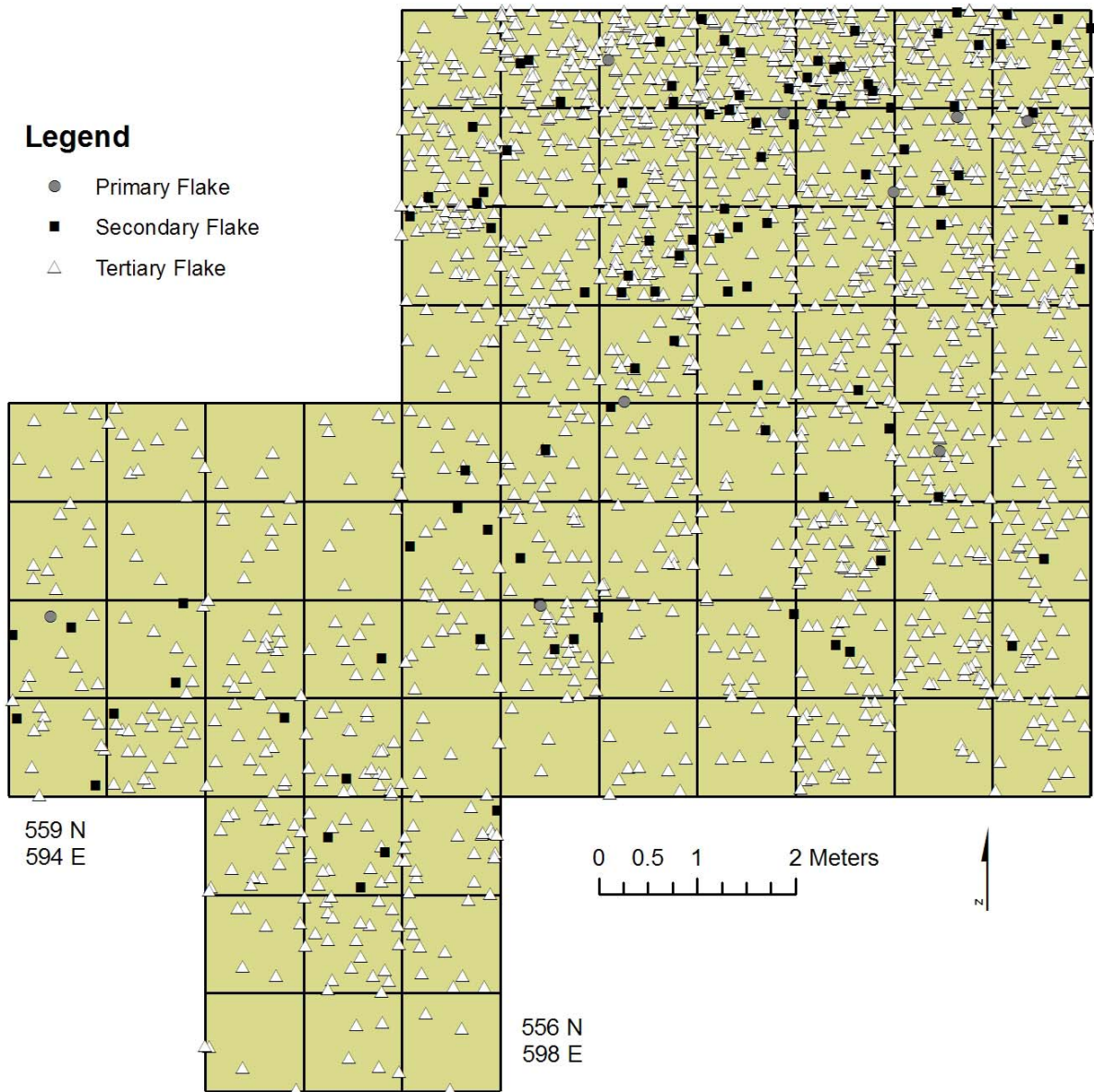


Figure 4.15: The location of the debitage according to artefact type.

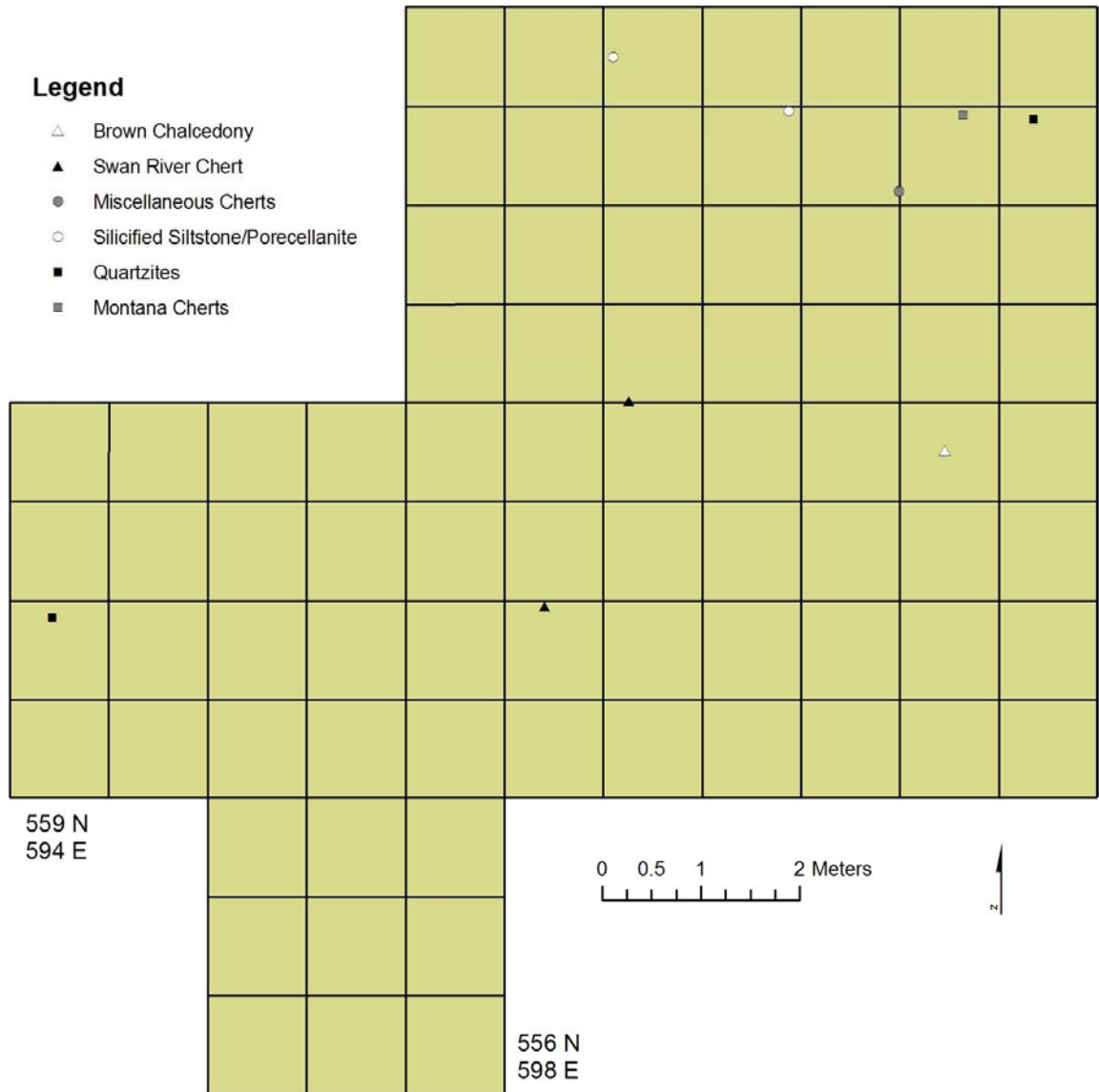


Figure 4.16: The location of the primary flakes according to material type.

The size of the debitage was also examined spatially (Figure 4.18). The majority 71% of the debitage recovered from the East Block, fell into the 6.6-25 mm category, followed by pieces of debitage ranging between 0-6.6 mm (27% of the debitage). A few flakes 25-50 mm and >50 mm were present, which together represent 2% of the total debitage from the East Block. The overwhelming majority of small sized debitage,

together with the predominance of tertiary flakes, suggests that flakes were being chipped off tools during the butchering process, and/or that tools were being re-sharpened.

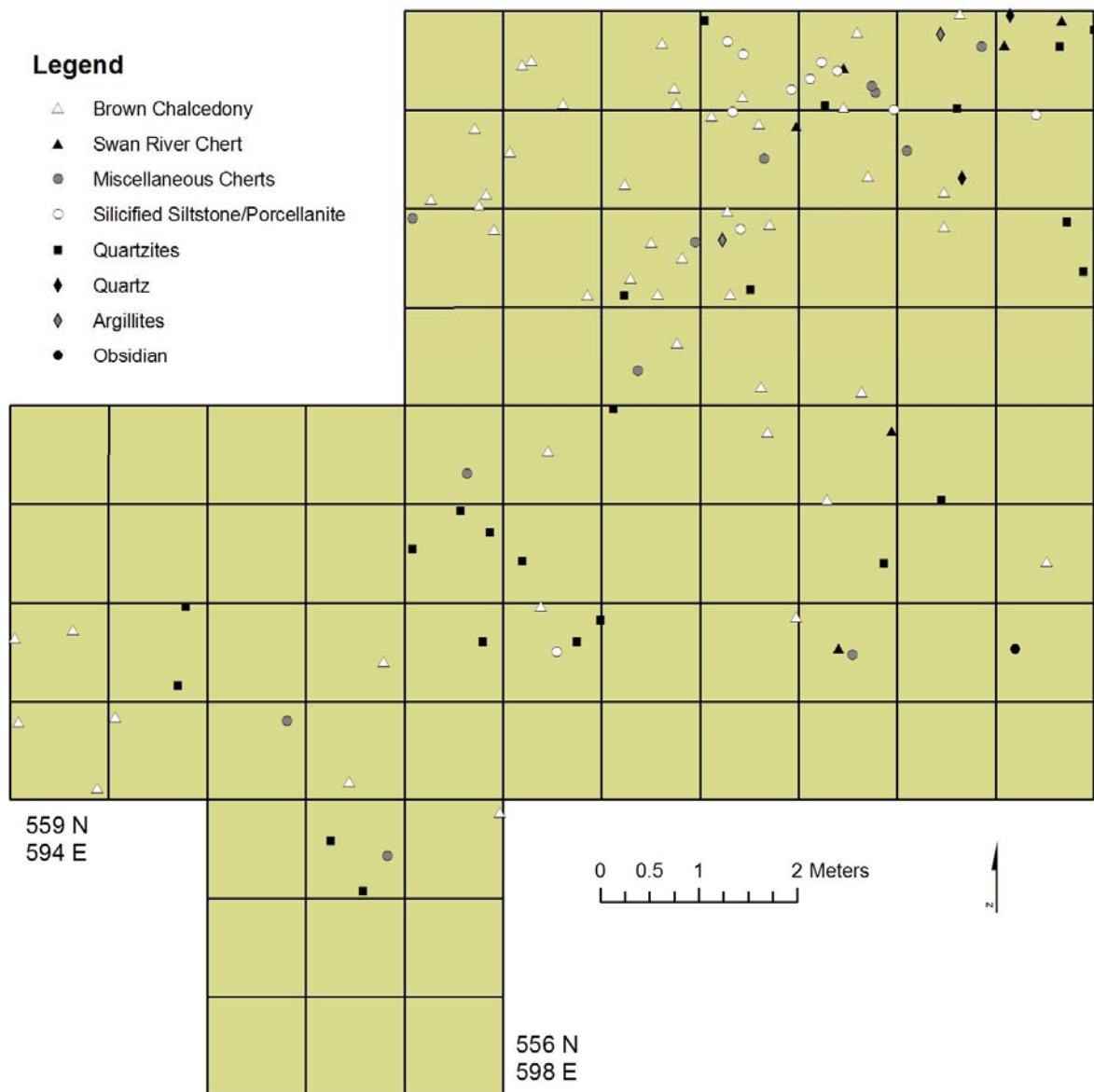


Figure 4.17: The location of the secondary flakes according to material type.

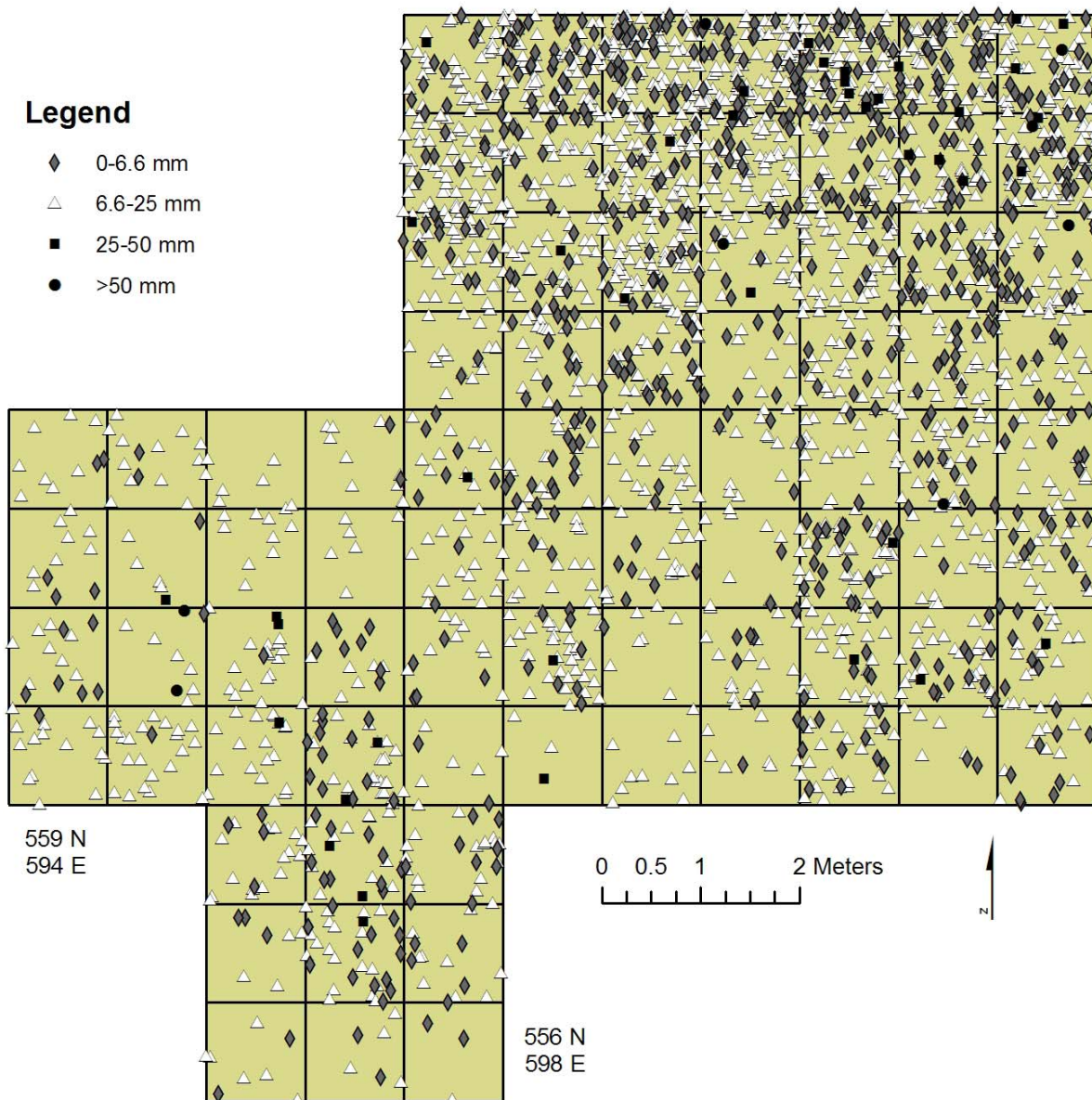


Figure 4.18: The location of all the debris according to size.

Since most debris fell into the 6.6-25 mm category, this grouping separated out into material type (Figure 4.19). As expected, the majority was brown chalcedony, but all nine material types were represented. Again, these pieces were concentrated in the northern extension.

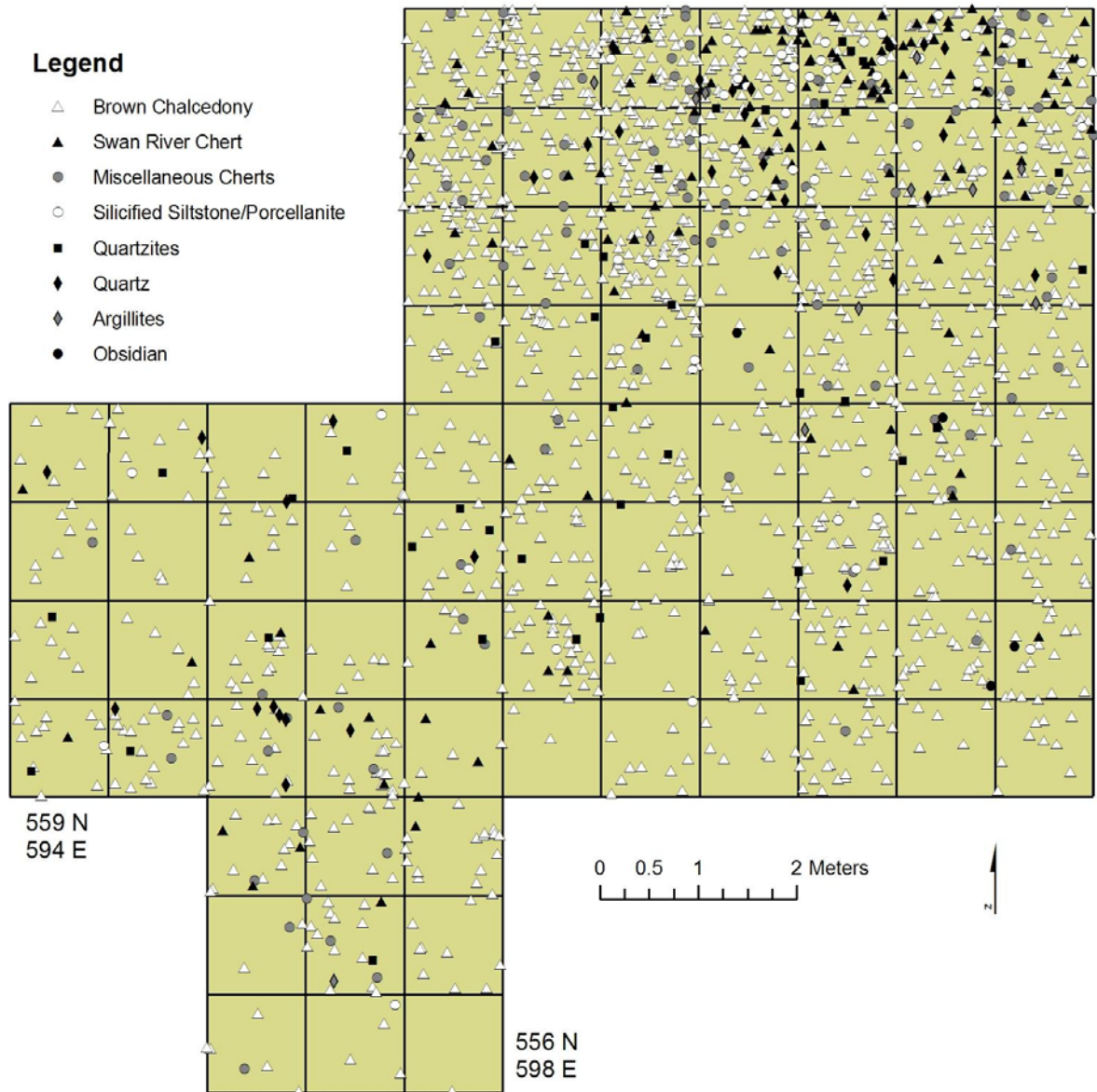


Figure 4.19: The location of all the 6.6-25 mm debitage according to material type.

The last spatial relationship examined was the relationship between the debitage and the lithic tools. As seen in Figure 4.20, 57 of the 94 lithic tools (61%) were found in the northern extension of the excavation block. Likewise, 63% of all the debitage were found there. Since this 28 1x1m unit area (35% of the East Block as a whole) yielded about 2/3 of the lithic artefacts, this spatial distribution is significant. Though beyond the

scope of this thesis, it would be interesting to examine the types of tools in relation to the debitage sizes. For example, areas of high numbers of micro-debitage and processing tools (scrapers, knives, etc.) may indicate butchering activity areas.

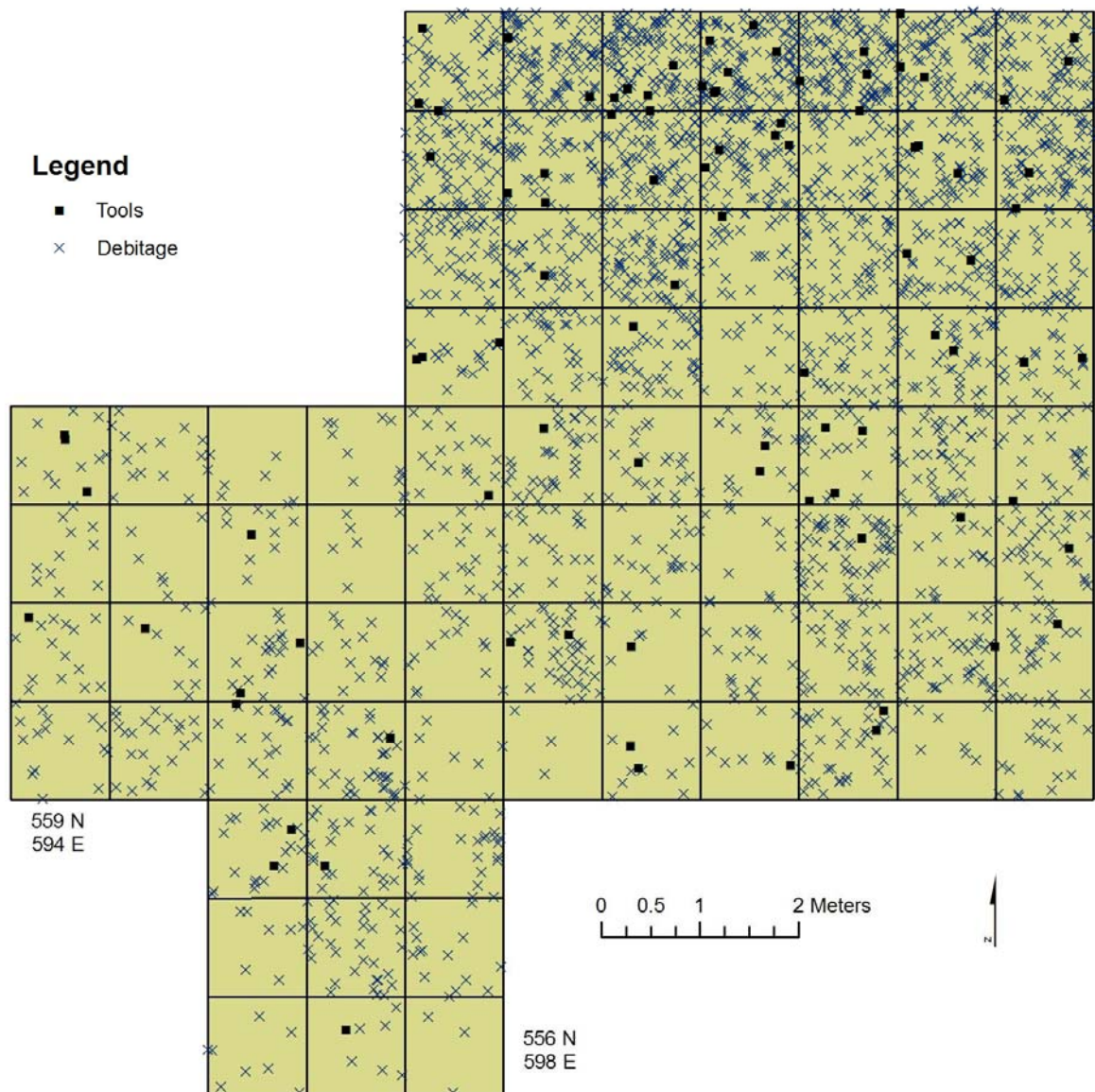


Figure 4.20: The location of all the debitage in relation to the lithic tools.

The large quantity of debitage unearthed in the Test Pits is worth examining as well, but because the units are spread out, the spatial distribution is difficult to quantify. Further excavation of this area may uncover other tool manufacturing areas.

Since the debitage data set was large, it was relatively easy to examine it spatially. The location maps and spatial statistical tests support a strong clustered relationship within the debitage. Though many more queries can be carried out, it is apparent that a better understanding of the spatial relationships can be inferred by using a GIS, in conjunction with spatial statistics.

Fire Broken Rock

Fire Broken Rock (FBR) was found throughout the site. The 101 pieces found in the West Area averaged 5.05 per square meter (Figure 4.21), while the Test Pits yielded 170 pieces averaging 28.33 pieces per square meter (Figure 4.22). In the East Block of the site, 878 pieces of FBR were found, with an average of 10.84 per square meter. Of the 1,149 pieces of FBR unearthed, 396 (34%) were recovered in the sieve. These pieces were included in the spatial analyses, randomly plotted the same way the debitage was.

The FBR was scattered across the East Block, but a few areas had more pieces than others (Figure 4.23). Within the East Block, the majority of FBR was found in the northwest corner. Though no defined hearth features were found during the excavations, the presence of FBR confirms the use of fire.

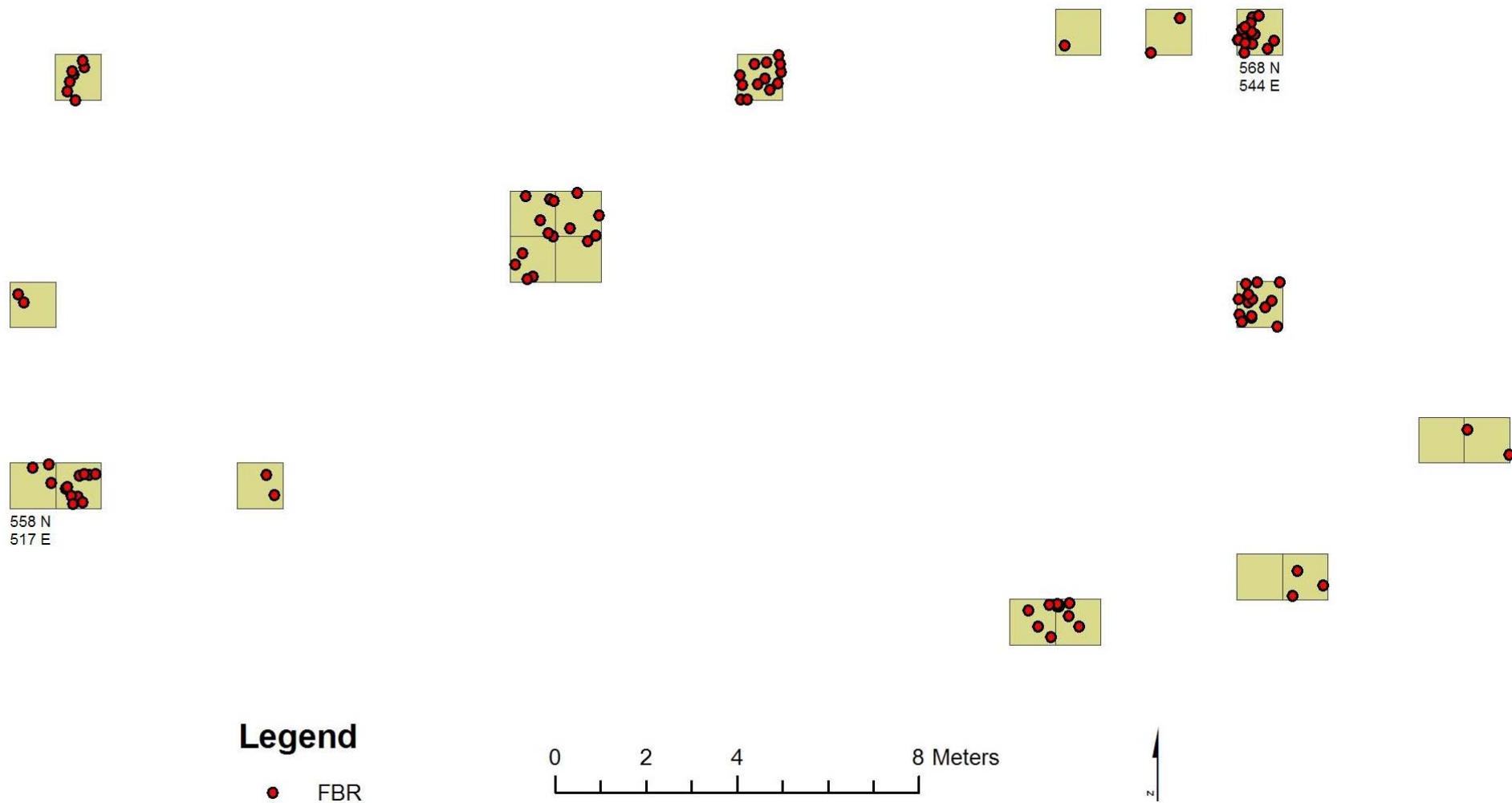


Figure 4.21: An overview of the location of all the FBR found in the West Area of the site.

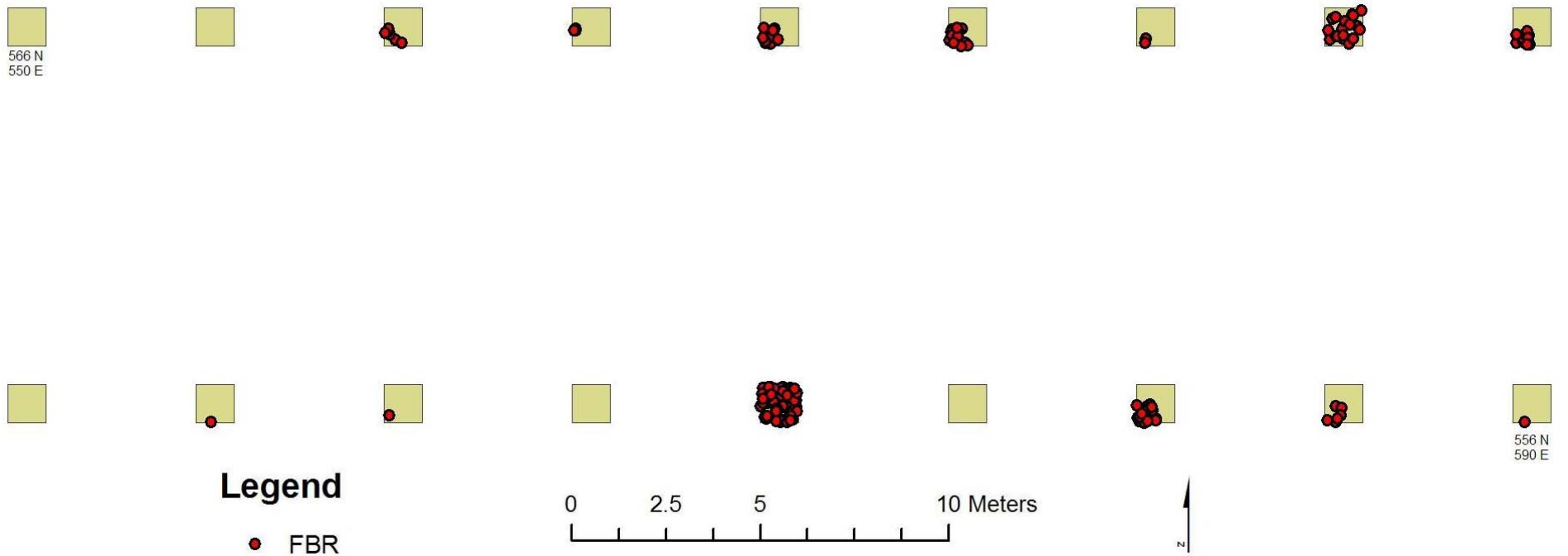


Figure 4.22: An overview of the location of all the FBR found in the Test Pits.

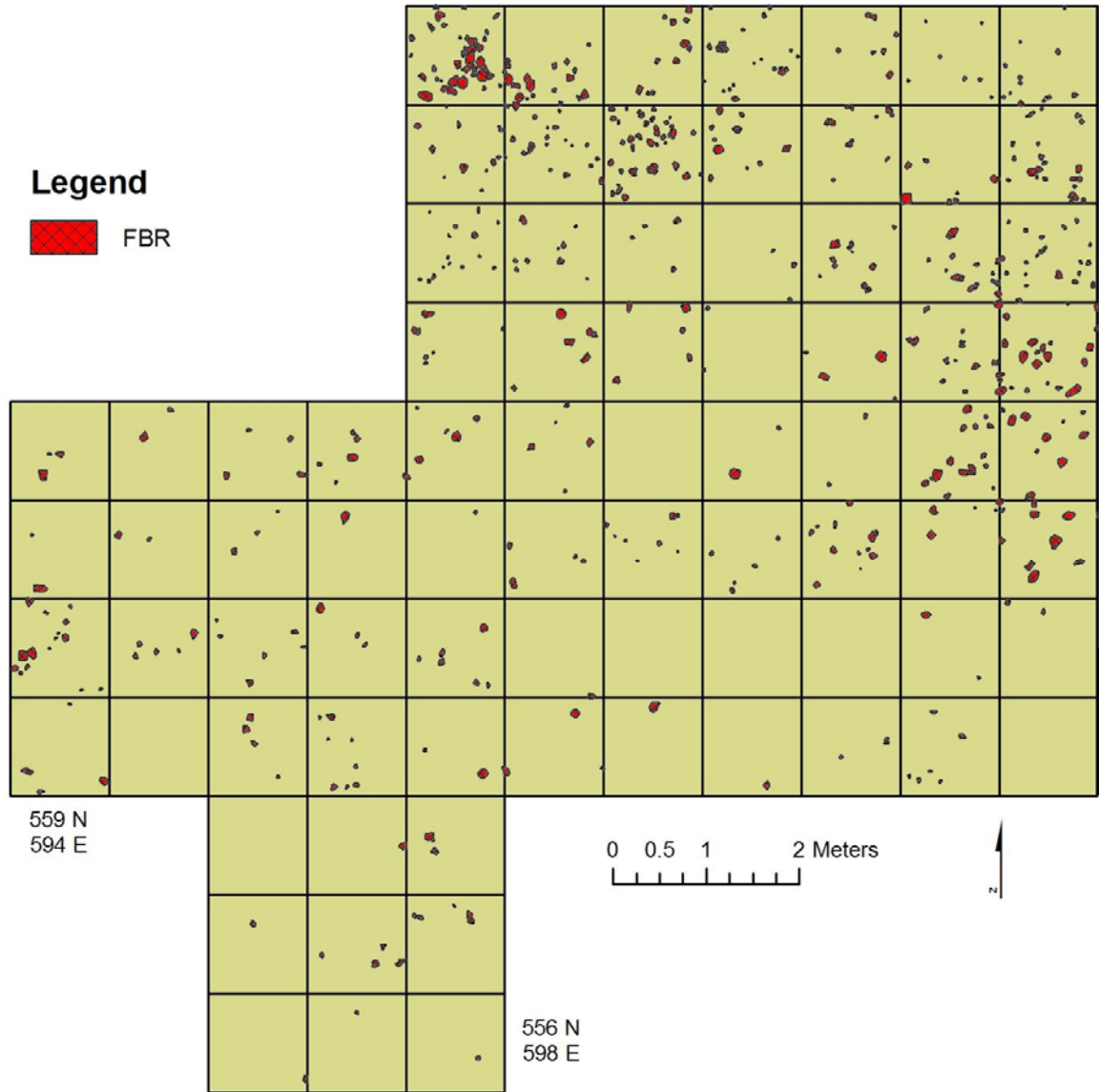


Figure 4.23: An overview all the *in situ* FBR (digitized as polygons) found in the East Block.

The nearest neighbour, Moran's I and Getis-Ord General G_i^* statistics all confirm a strong clustered distribution of the FBR (Table 4.7). The calculated significance levels, which are all less than a 1% probability error, further support these results.

Table 4.7: Results from the nearest neighbour, Moran's I and Getis-Ord General G_i^* spatial statistical tests carried out on the FBR from the East Block.

	Ratio/Index	z-score	Significance Level
Nearest Neighbour	0.689	-2.58	0.01
Moran's I	0.069	2.58	0.01
Getis-Ord General G_i^*	0.360	2.58	0.01

The results from the Ripley's K statistical test also verify the clustered distribution of the FBR in the East Block. Over the ten distance bands, the spatial relationship between the FBRs became stronger as more data points were included.

Table 4.8: Results from the Ripley's K statistical test carried out on the FBR data from the East Block.

Distance	L(d)
0.05	0.810
0.10	0.880
0.15	0.950
0.20	1.019
0.25	1.088
0.30	1.155
0.35	1.226
0.40	1.292
0.45	1.360
0.50	1.429

Quadrat analysis was also carried out on all the FBR from the East Block. Based on Figure 4.24, a significant number of FBR was found in the northwest area. KDE (Figure 4.25) output five distinct areas where the FBR were concentrated, all located in the northern extension. Clearly, the prevalence of FBR and lithic tools in this part of the site suggest a concentration of cultural activities (manufacturing and processing).

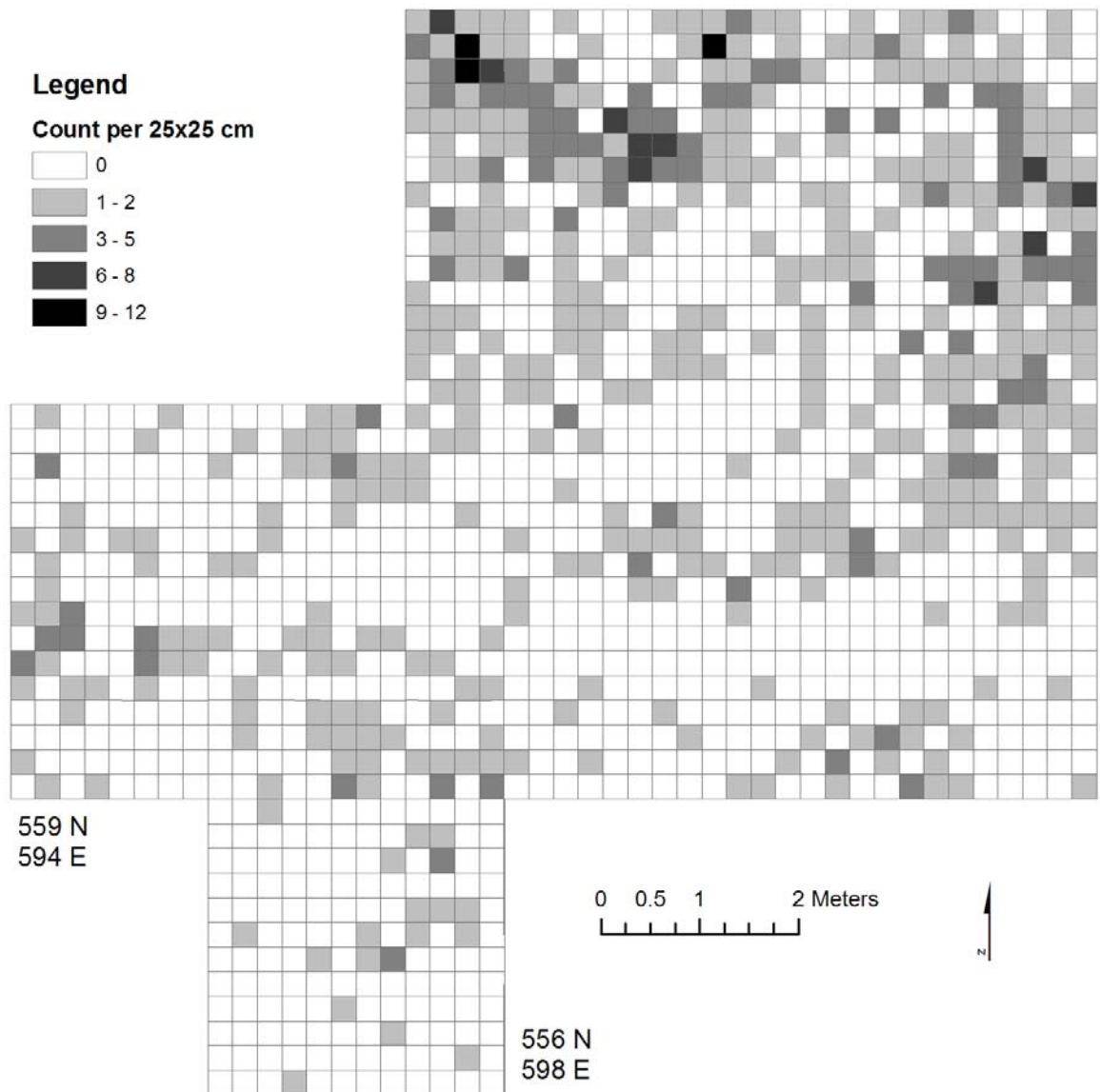


Figure 4.24: Quadrat analysis results for all the FBR from the East Block.

In addition to the statistical tests carried out on the FBR data, specific queries that related to the nature of the FBR were investigated. The angularity of the FBR, for example, may relate to cooking or grease rendering activities. As rocks are exposed to thermal change (i.e. being heated in a fire and subsequently placed into water) they may fracture. Though the degree of angularity also relates to the type of rock being used, this

activity will yield a higher percentage of angulated rock when compared to stones simply heated in a hearth. Fire broken rocks with 2-4 fractured facets (medium angularity) represent 64% of the total found in the East Block. Fire broken rocks exhibiting high angularity (five or more facets) represent 29%, while low angularity (0-1 facets) represent 7% of the total FBR found in the East Block.

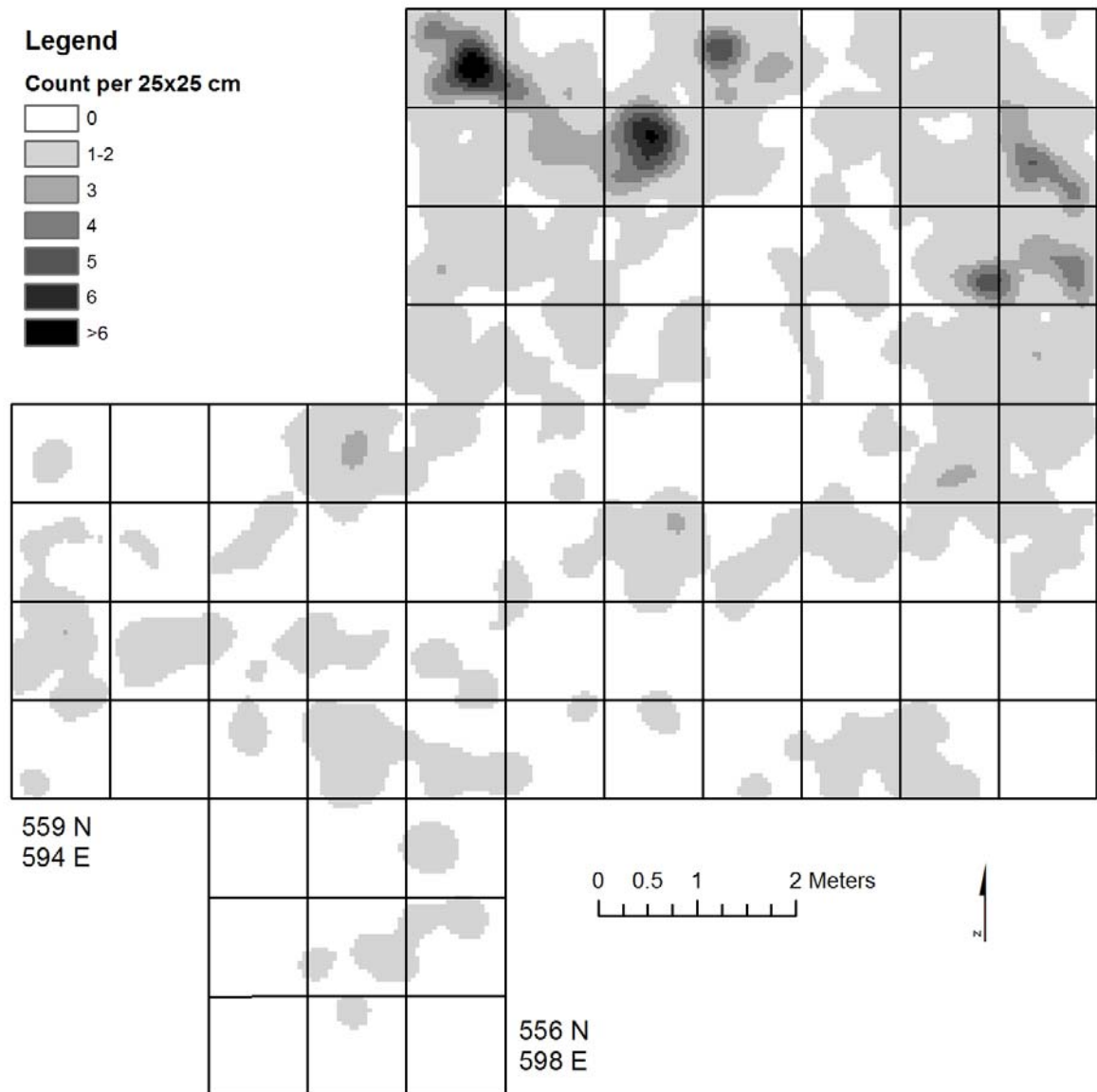


Figure 4.25: Kernel density estimation results for all of the FBR found in the East Block. There were five dense concentrations, all located in the northern extension.

Figure 4.26 shows the distribution of FBR based on angularity. Though clusters of FBR are apparent in certain areas of the East Block, all three types of angularity were represented consistently. This distribution suggests that these rocks may have been used in cooking or grease rendering across the site.

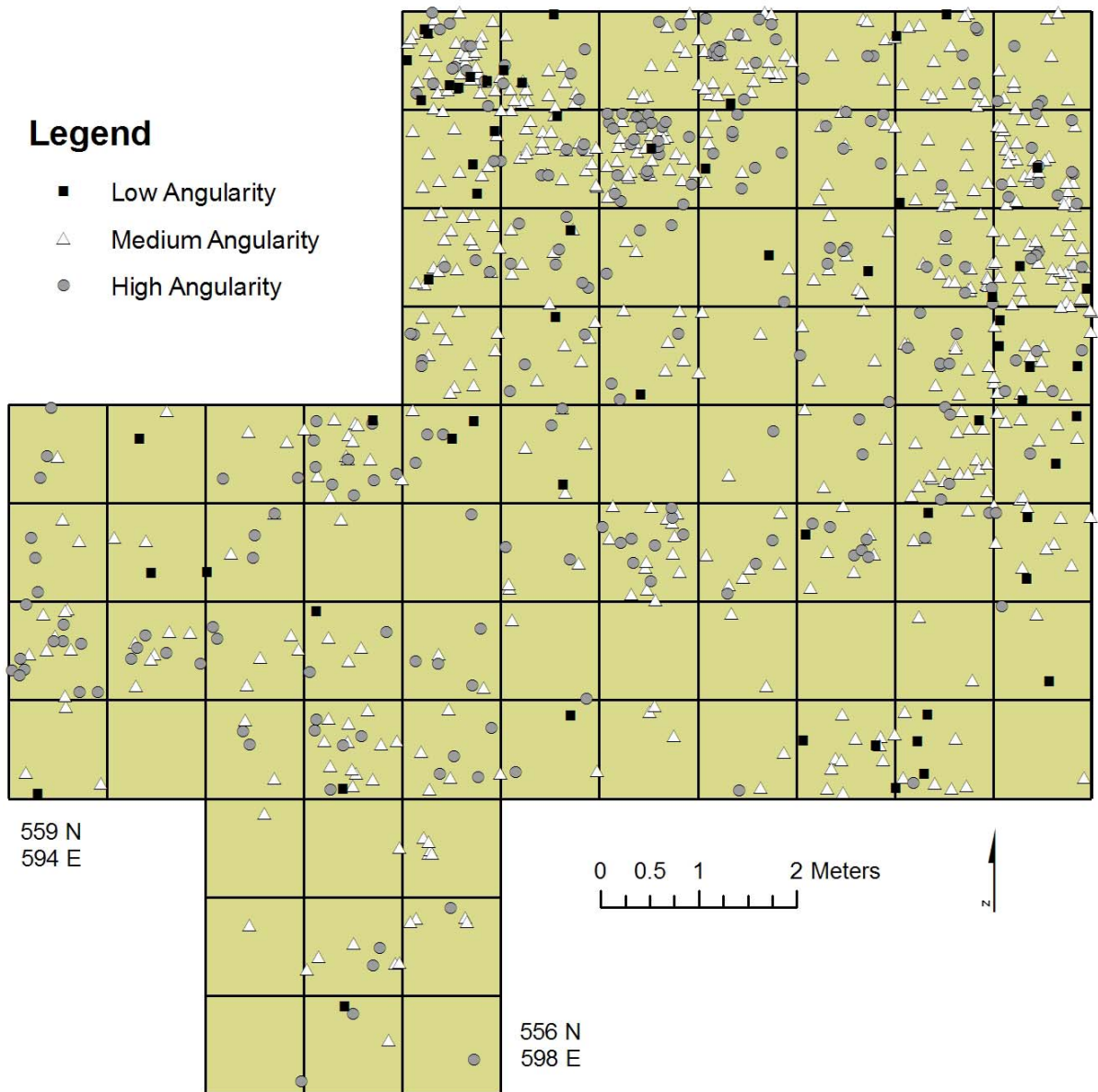


Figure 4.26: The location of all the FBR according angularity.

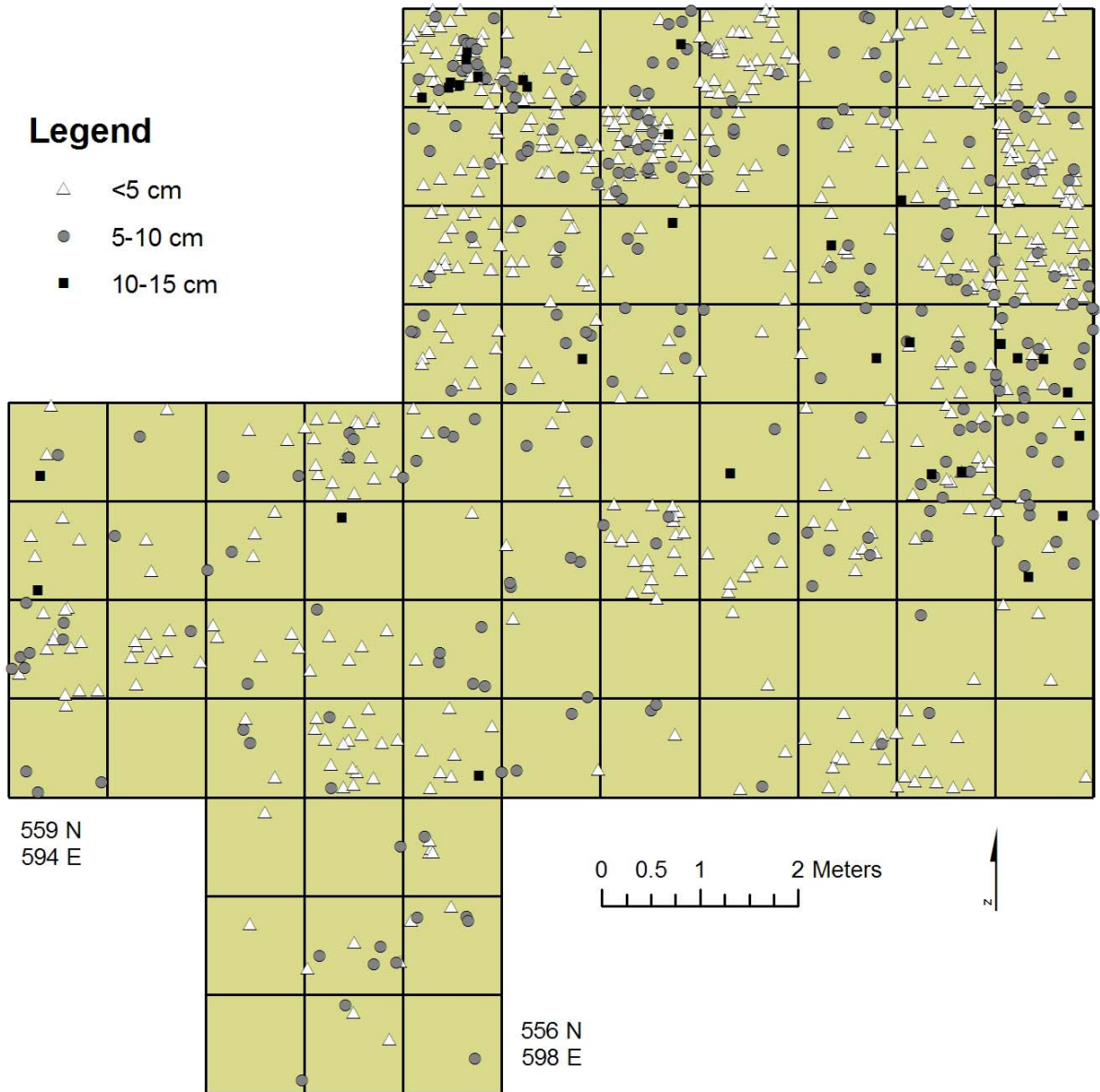


Figure 4.27: The location of all FBR according to size.

The size of the FBR can also relate to cooking or grease rendering (Figure 4.27). Rocks used a number of times will break into smaller and smaller pieces as they experience thermal change, resulting in a larger quantity of smaller pieces. The two dominant size categories of the FBR are <5 cm (68% of the total FBR in the East Block) and 5-10 cm (29%), with a few pieces falling into the 10-15 cm category (3%). This

assemblage suggests that the rocks used in cooking and boiling activities were used multiple times.

The FBR used at a site is usually collected locally because it is heavy to transport. However, some rocks are better than others are for cooking activities. Rocks that absorb too much water and are, therefore, easily fractured when heated (such as sandstone) are less useful than quartzites and granites (Brink and Dawe 1989: 67-68; Brink and Dawe 2003: 93).

The dominant material utilized in the East Block was the granite/gneiss group, which represents 52% of the FBR found, followed by the quartzite group (33%). The 'Other' category (3%) includes phyllite, schist and shale. Interestingly, sandstone represents 12% of the total FBR from the East Block. Since this was not an ideal material type to use because of the reasons stated above, specific rock selection may not have been a priority at the site. In order to test this hypothesis, a survey of the rock types available in the area needs to be conducted to compare locally available rock frequencies with the FBR types used. Figure 4.28 shows the distribution of the FBR material types that were found in the East Block. In the areas where there were high concentrations of FBR, all material types were present.

Some of the FBR was able to be refitted. Refitting FBR artefacts is done to locate cultural activity areas, such as hearths and boiling pits. There were 62 pieces in 24 refitted groups, which make up 7% of the FBR found in the East Block (Figure 4.29). Some pieces were found quite far from each other, moved across the site culturally or naturally, while others were within a few centimetres of each other. Within the East Block, the majority of the refits were from the northern extension, where the

concentration of the FBR was the highest. This further supports the suggestion that cooking, and/or grease rendering took place in this part of the site.

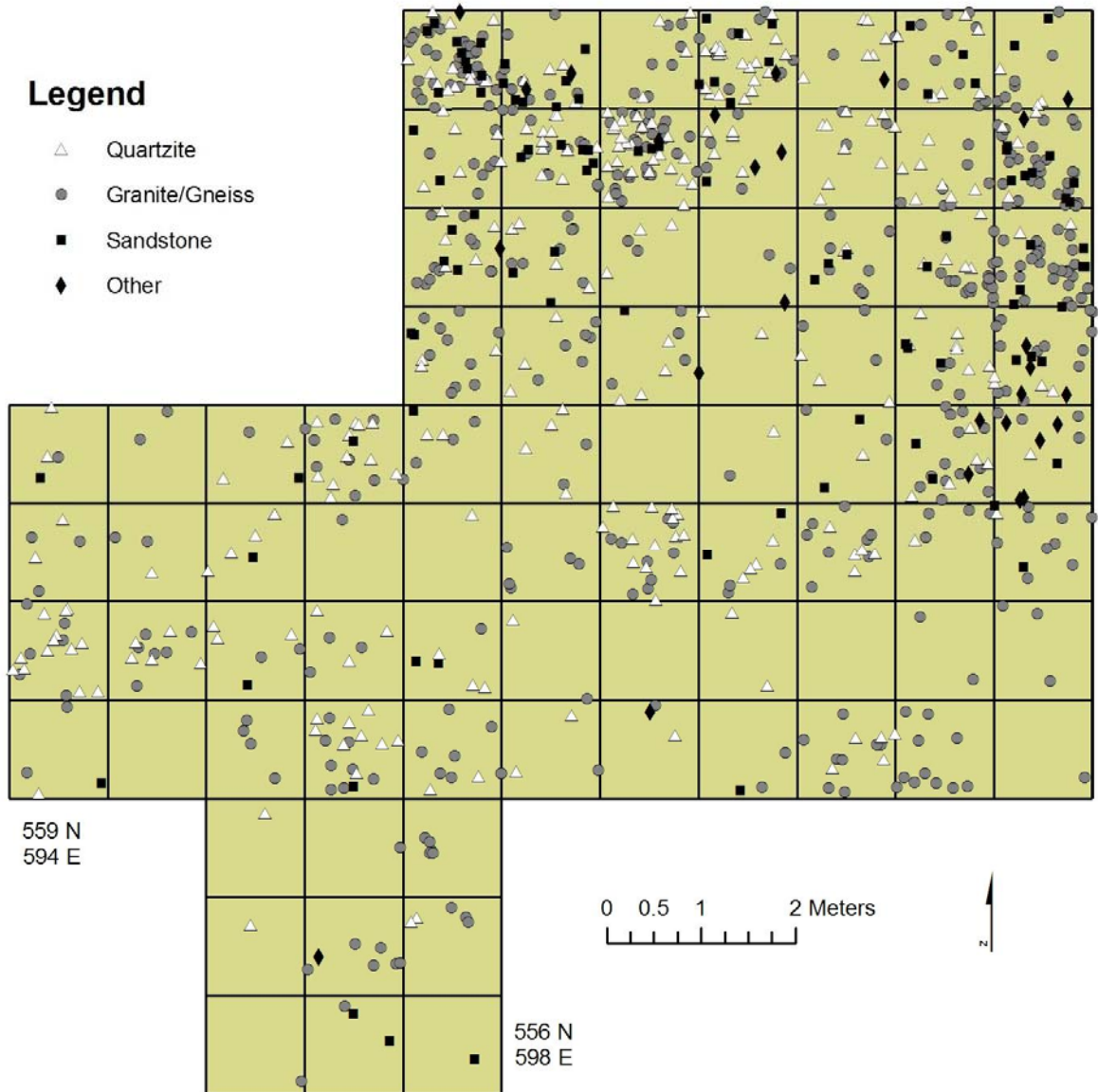


Figure 4.28: The location of all of the FBR by material type.

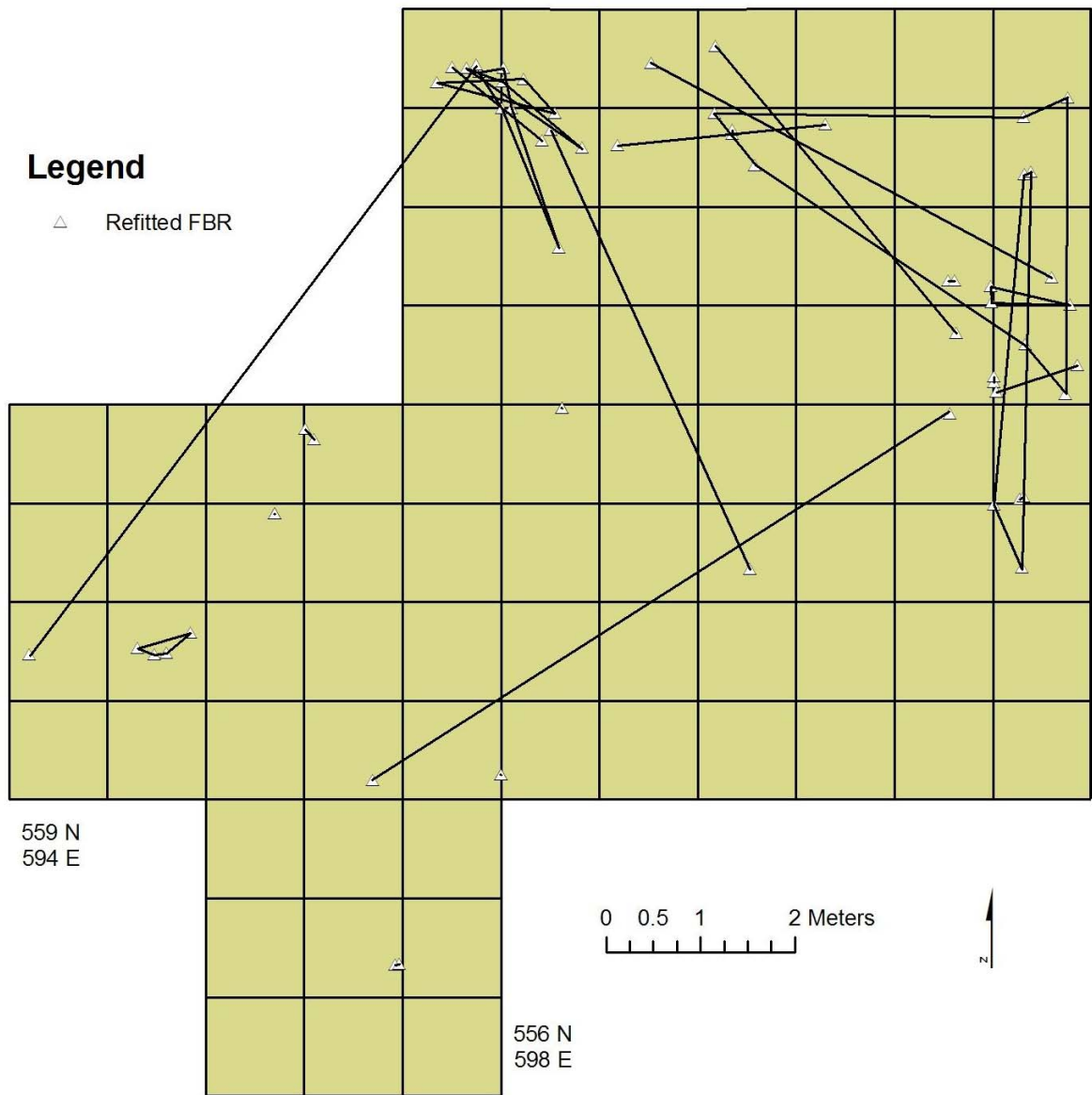


Figure 4.29: Distribution map showing where the FBR refits were located.

The study of the FBR was useful because it provided information relating to the processing activities that took place at the site. The GIS spatial analyses confirmed a concentration of cultural activity in the East Block. The high number of FBR found in the Test Pits is also noteworthy. Expanding this area of the site may uncover grease

rendering or hearth areas complimenting the possibility of lithic manufacture here.

Without the use of the GIS, some of these relationships may not have been detected.

Fauna

Faunal remains (bone ecofacts) were the most abundant archaeological remain found at the site. In the West Area, 1,242 faunal remains were recovered, averaging 62.1 per square meter (Figure 4.30). The Test Pits yielded 300 bone fragments, averaging 50 per square meter (Figure 4.31).

It was in the East Block that the faunal remains were most plentiful, with a total of 12,197 were recovered, averaging 150.58 per square meter. As with the debitage and FBR, sieve fauna were included in the spatial analysis. Out of the 12,197 identifiable faunal remains, 10,220 were found *in situ*. The 1,977 pieces of identified sieve fauna were randomly plotted in the 1x1 m units they were excavated from.

Figure 4.32 shows the digitized location of the *in situ* faunal remains in the East Block. Figure 4.33 displays these and the identifiable sieve faunal remains plotted as point data. Based on this distribution, the fauna is highly concentrated in the east and towards the north. It is difficult, however, to interpret patterns from this distribution because of the high numbers of remains. Thus, it was important to examine these ecofacts using spatial statistics.

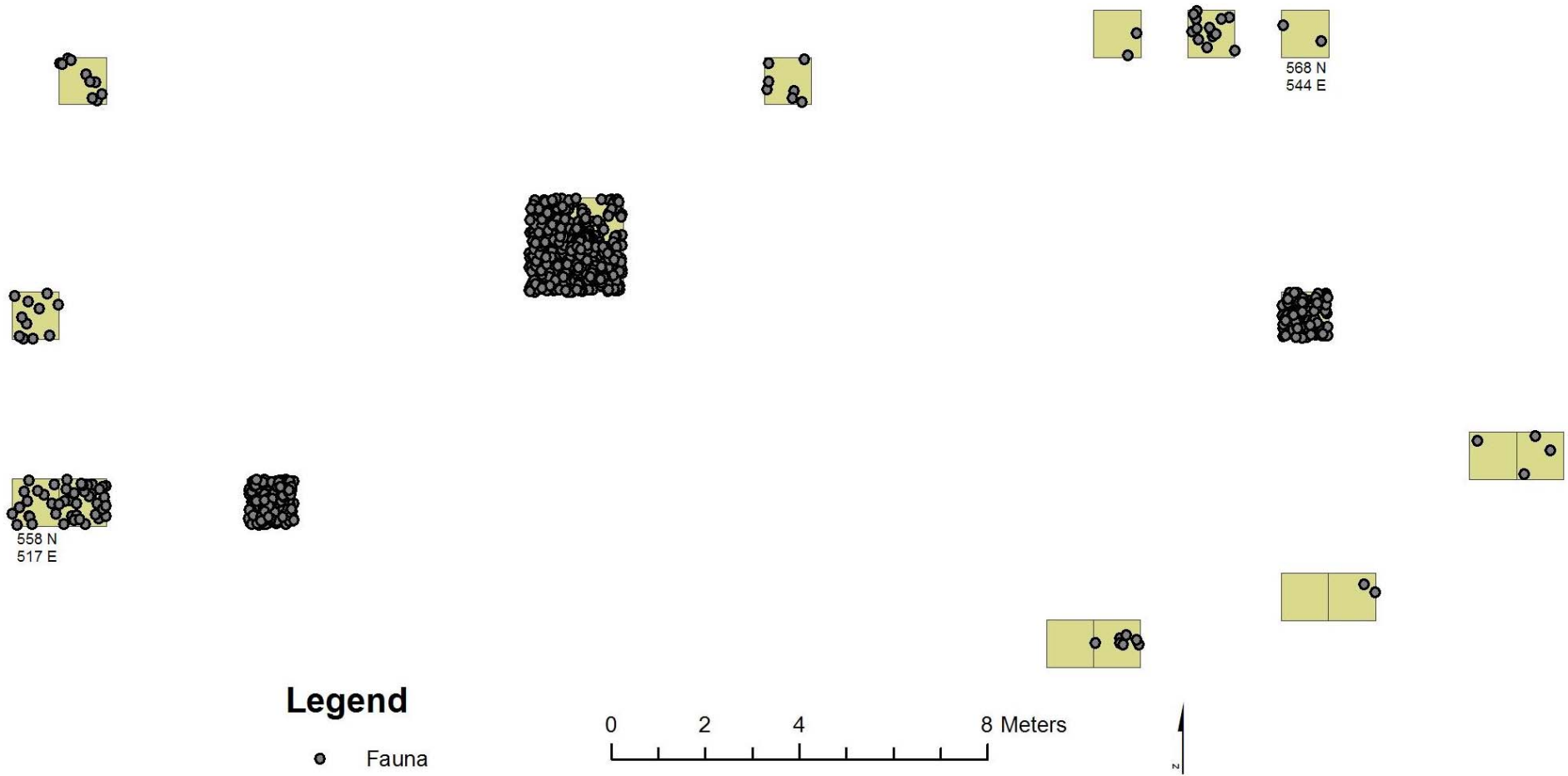


Figure 4.30: An overview of the location all the fauna found in the West Area of the site.

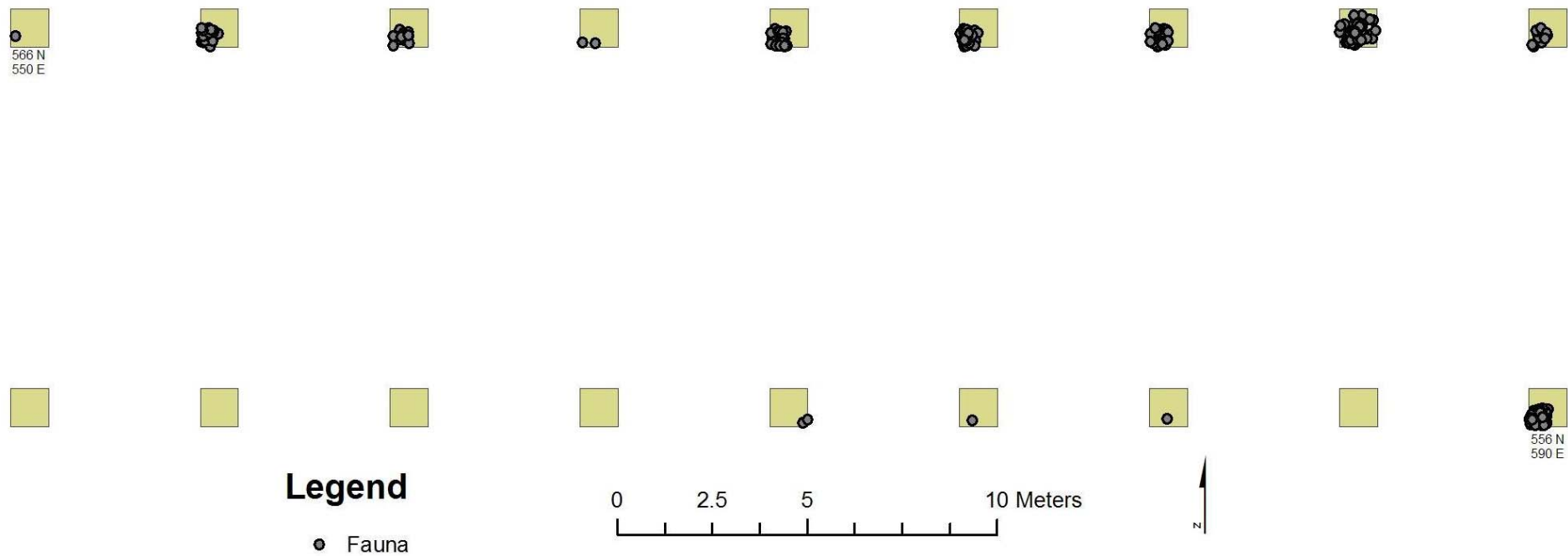


Figure 4.31: An overview of the location of all the fauna found in the Test Pits.

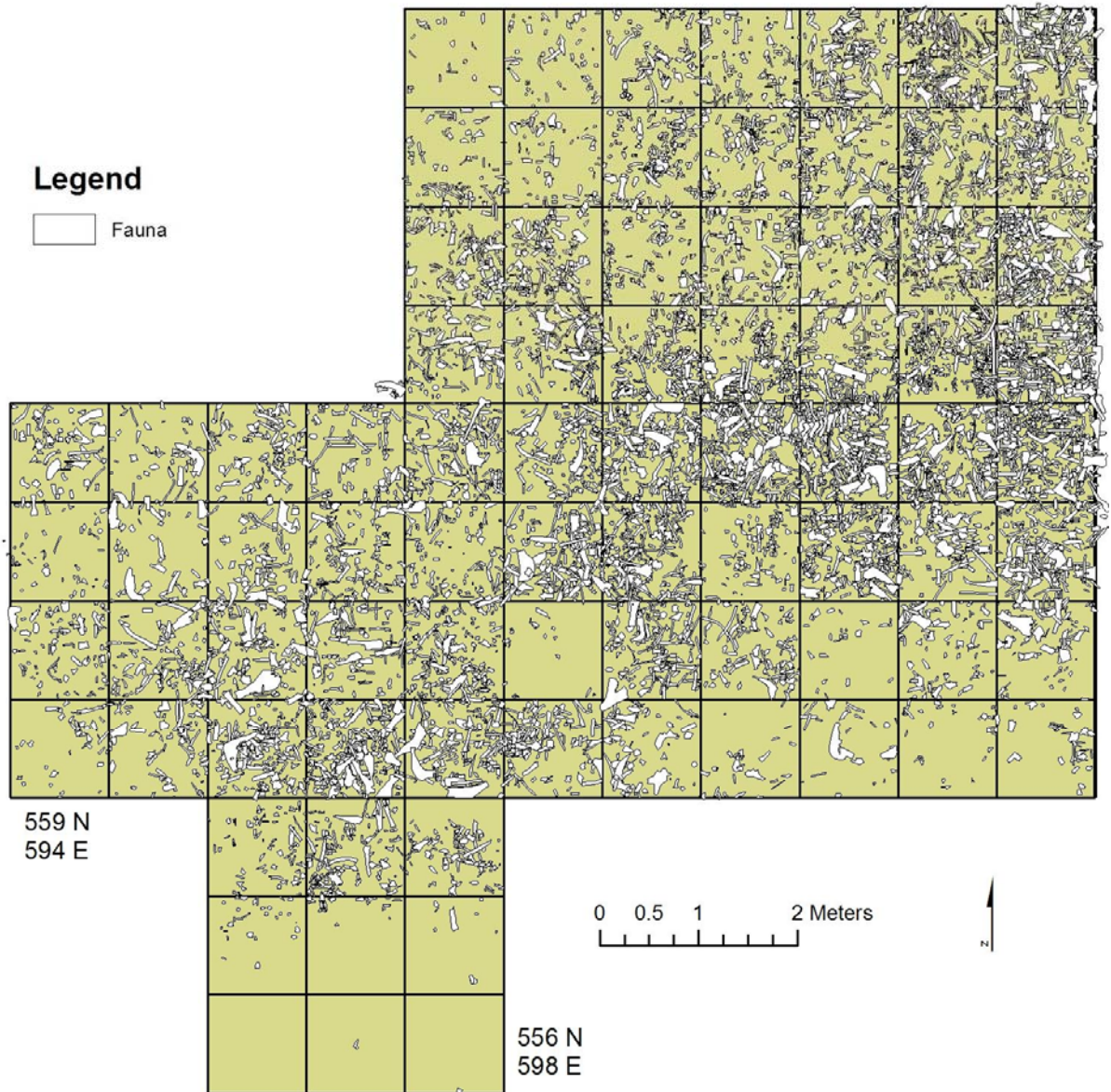


Figure 4.32: An overview of the location of the *in situ* fauna (digitized as polygons) found in the East Block. Unit 560 N 599 E was looted in 2005.

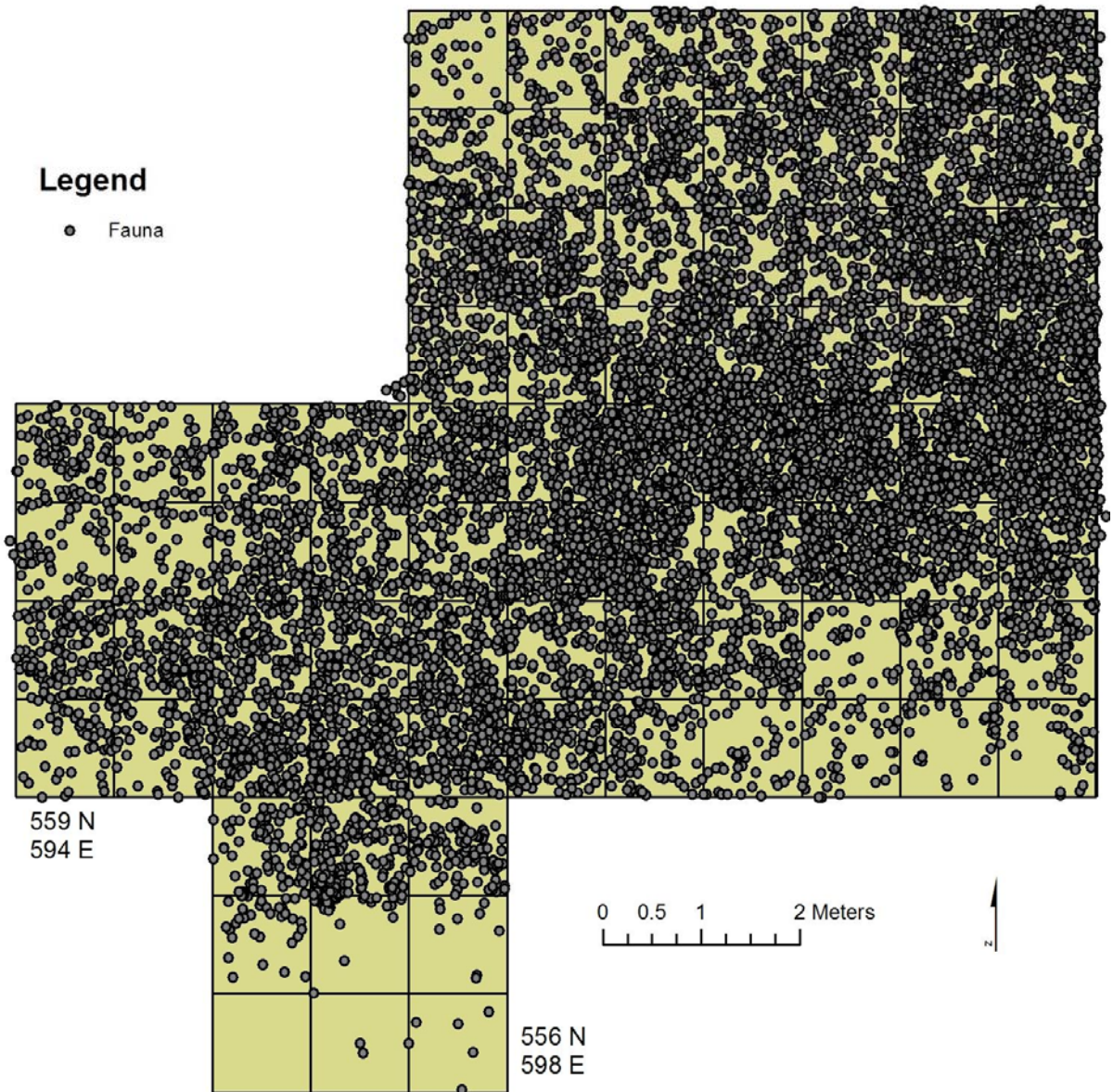


Figure 4.33: An overview of the location of all the fauna found in the East Block.

The nearest neighbour ratio with the Moran's I and Getis-Ord indices support the clustered distribution (Table 4.9), with calculated significances of 0.01. The results from the Ripley's K statistical test confirm the clustered distribution of faunal remains in the East Block (Table 4.10).

Table 4.9: Results from the nearest neighbour, Moran's I and Getis-Ord General G_i^* spatial statistical tests carried out on the faunal data from the East Block.

	Ratio/Index	z-score	Significance Level
Nearest Neighbour	0.734	-2.58	0.01
Moran's I	0.144	2.58	0.01
Getis-Ord General G_i^*	0.360	2.58	0.01

Table 4.10: Results from the Ripley's K statistical test carried out on the faunal data from the East Block.

Distance	L(d)
0.05	0.647
0.10	0.707
0.15	0.768
0.20	0.828
0.25	0.889
0.30	0.950
0.35	1.012
0.40	1.074
0.45	1.135
0.50	1.197

Quadrat analysis and KDE were also carried out on the faunal remains from the East Block. Based on the results, it is clear that the highest concentrations of bone were located towards the east, as well as in the north (Figure 4.34). When compared to the plotted point data (see Figure 4.33), this distribution map is easier to interpret because it gives the actual counts of the remains within a specified area (0.25 m). The results from the KDE method (Figure 4.35) also show the location of pockets of highly concentrated faunal remains. The concentrations can be easily seen and interpreted in this visual output.

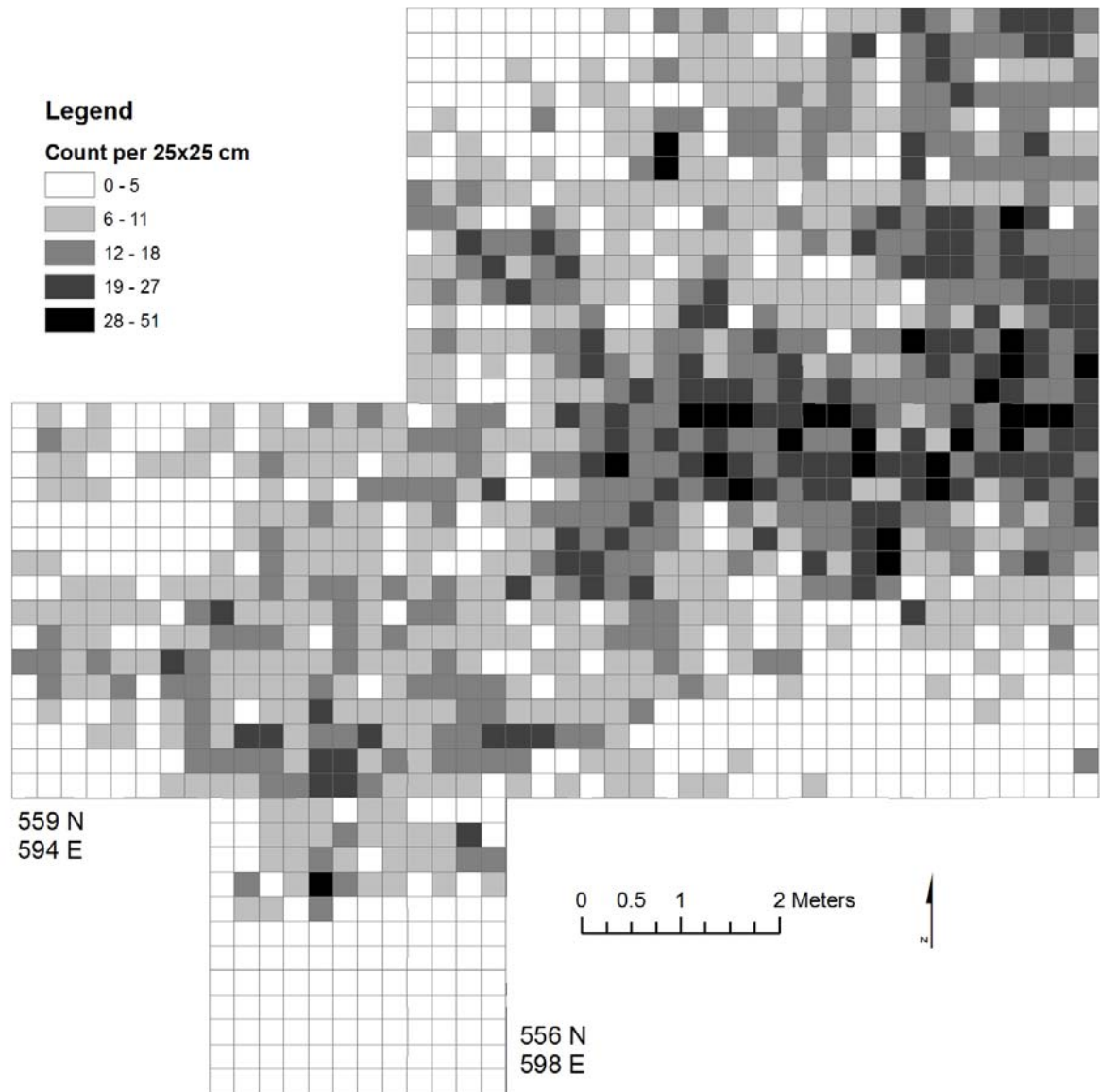


Figure 4.34: Quadrat analysis results for all the fauna from the East Block.

Beyond density concentrations, specific cultural activities were difficult to detect because of the high number of faunal remains uncovered in the East Block. Therefore, the fauna was separated out into meaningful groups (based on anatomical location) to assist in the interpretation of butchering activities.

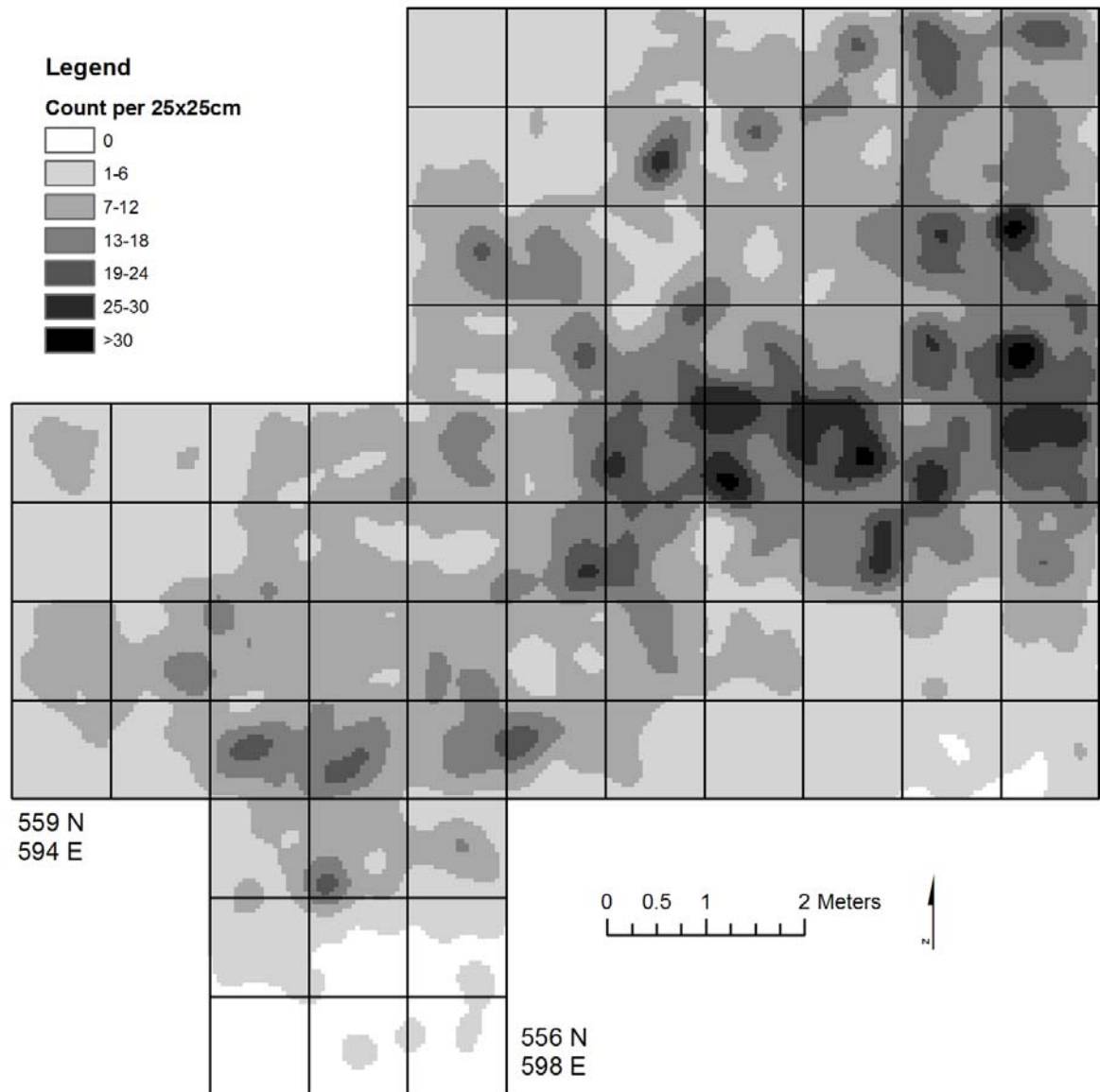


Figure 4.35: Kernel density estimation results for all of the fauna found in the East Block.

Primary butchering involves the disarticulation of the animal carcass into units for meat removal, and includes hide removal, joint dismemberment (disarticulation) and meat removal (Binford 1978b: 63; Lyman 1994: 295; Reitz and Wing 1999: 128; Watts 2008: 21). Articulation portions denote primary butchering activities, as does direct evidence on the bones in the form of cut marks and fracture patterns (butchering breaks).

Cut marks are straight grooves that are created when a sharp tool, such as a knife, comes into contact with the bone. These marks are produced during hide removal, meat removal and joint dismemberment (Binford 1981: 47; Lyman 1994: 298; Reitz and Wing 1999: 129; Watts 2008: 23). The most common fracture pattern that is associated with primary butchering is the spiral fracture. The spiral fracture is associated with joint dismemberment and is defined as a smooth U-shaped fracture on the shaft of the bone (Lyman 1994: 319; Reitz and Wing 1999: 129; Watts 2008: 27)

Secondary butchering includes activities, such as meat stripping, marrow extraction and grease rendering (Watts 2008: 21). Evidence of secondary butchering include cut marks, impact marks and fracture patterns. Secondary cut marks are seen during meat stripping, i.e., the removal of meat from bones to make food stores (Reitz and Wing 1999: 128; Watts 2008: 23). The spiral fracture can result from secondary butchering activities (Lyman 1994: 300; Reitz and Wing 1999: 130; Watts 2008: 27). They are created when the bone is smashed open to remove the marrow. Impact marks are notches left on a bone from the striking of a blunt object on the bone and are associated with marrow extraction and the breaking of bones into smaller pieces to extract grease (Lyman 1994: 298; Reitz and Wing 1999: 130; Watts 2008: 22).

Differentiation between primary and secondary butchering is difficult. The spatial relationships between specific elements, those bones with cut marks or spiral fractures, and other artefacts (such as choppers, scrapers and fire broken rock) help in this assessment.

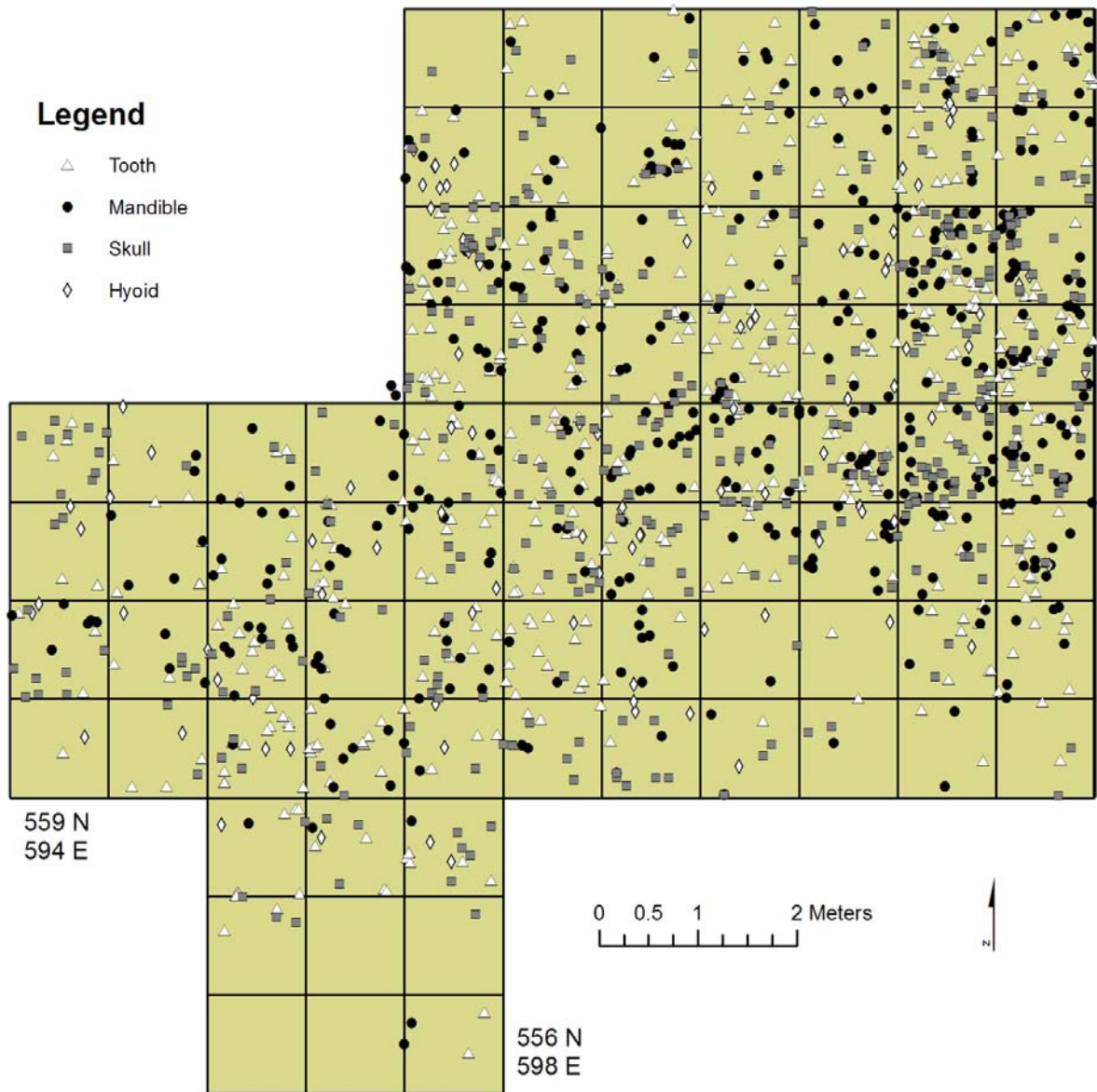


Figure 4.36: The location of the cranial elements from a bison skeleton in the East Block.

The first anatomical group that was examined included the cranial elements (skull, mandible, hyoid and teeth). The distribution map displayed in Figure 4.36 shows that these elements were spread throughout the East Block. Clustering was not as apparent, but they follow the general trend of the faunal remains seen in Figure 4.35. It is not surprising that the tooth group was the most abundant element since there are more of

them in a bison skeleton than others of this group, and they can fall out of the mandible or maxilla to be recorded individually. The tooth group represents 5% of the total faunal remains recovered from the East Block, which is higher than that of the mandible (3%), skull (3%) and hyoid (< 1%) groups in comparison.

The skull is represented by only a small number of recovered faunal remains. There were no intact or even large portions of the skull found, which suggests they were either poorly preserved, are located in another part of the site or that they were smashed during the butchering process. The lack of skulls at the site may also reflect removal for ceremonial purposes (Shortt 1993: 82; Brink 2008: 216). Mandibles on the other hand, were well preserved at the site and correspond in location to the skull fragments that were found. Because the hyoid is small and less dense, it typically does not preserve as well as other bones and, therefore, it is not uncommon to have relatively few represented at a site. That being said, 98 pieces of these bones were recovered from the East Block, including the thyrohyoid, which is a very small hyoid bone. The recovery of these and other small bones confirm the well preserved context of the bone bed. The hyoids were found throughout the excavation block, but are more clustered in the northern extension.

The skull, atlas, axis and cervical vertebrae were also grouped together and examined because primary butchering involves separating the skull from the rest of the animal. When the skull was removed, the atlas, axis and some cervical vertebrae may be removed with it. The atlas and axis combined represent less than 1% of the fauna and the cervical vertebrae 3% of the remains found at the site. Again, it could be that these elements are located in an unexcavated part of the site or that they may have been

removed from the site with the skull. Based on the distribution displayed in Figure 4.37, this group follows the general trend of the faunal remains.

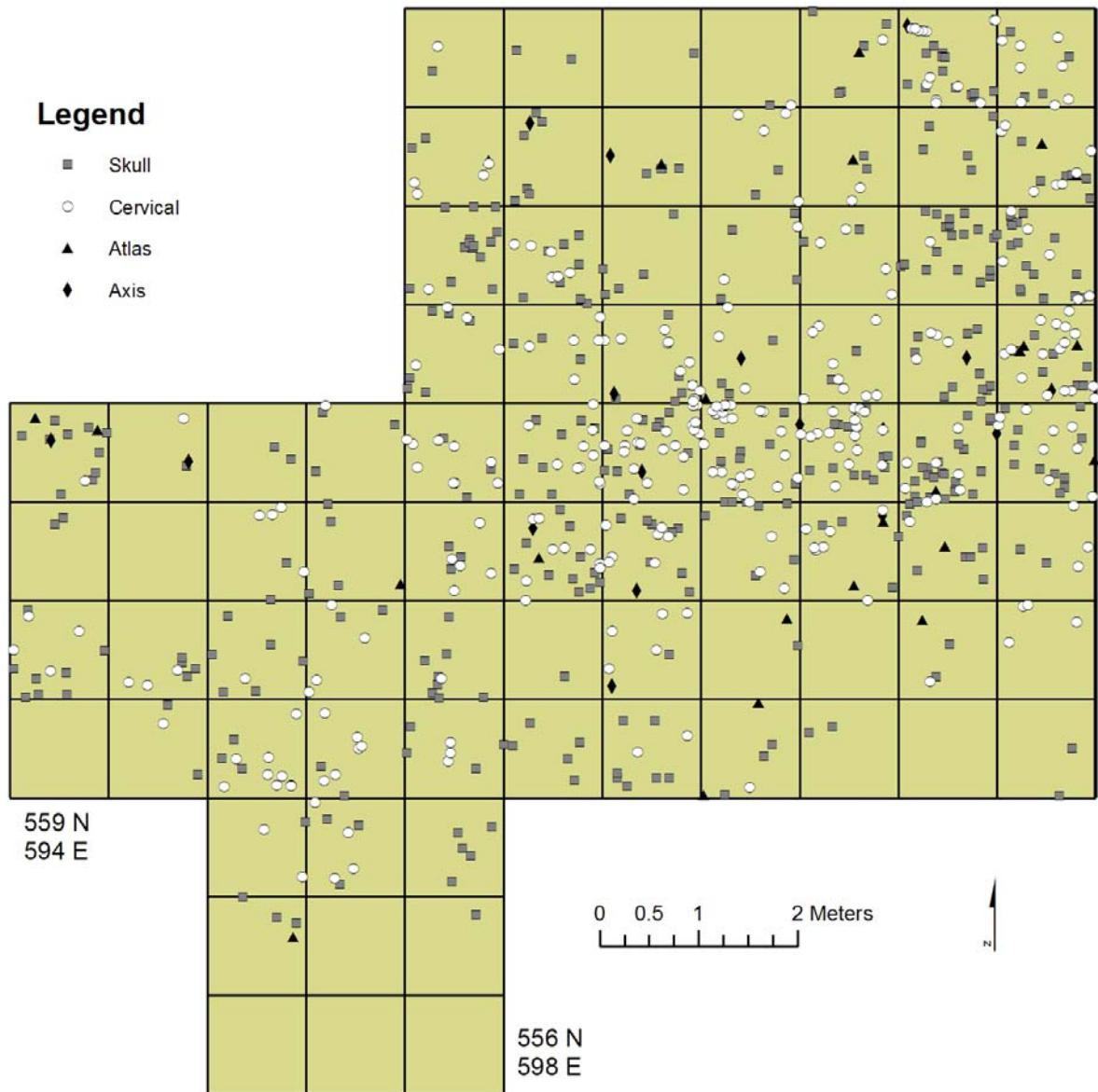


Figure 4.37: The location of the skull, atlas, axis and cervical vertebrae in the East Block.

The next anatomical group included the lumbar and thoracic vertebrae, the sternum, ribs and cartilage. These elements were put into a group together because they are the core elements of the skeleton. Figure 4.38 display their location. The thoracic vertebrae represent 5% of the total fauna, which were found throughout the site. There

was a large section of articulated thoracic vertebrae found in unit 562 N 602 E, resulting in a higher concentration in that area.

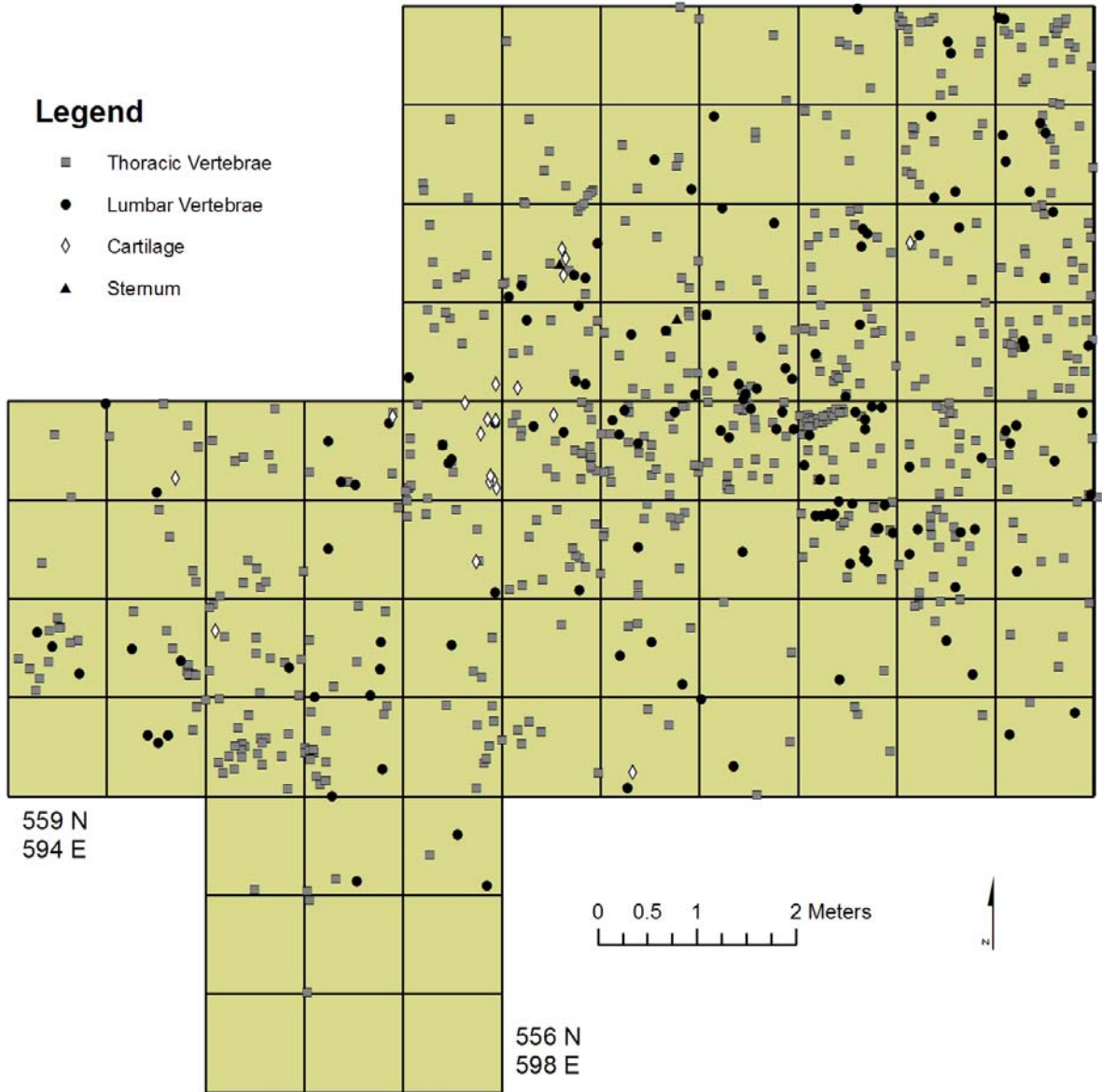


Figure 4.38: The location of the core elements of a bison (thoracic and lumbar vertebrae, cartilage and sternum) in the East Block.

The sternum and cartilage together represent less than 1% of the total fauna, but the cartilage pieces are only located in one area of the East Block with a few pieces scattered elsewhere. It was surprising to find cartilage at the site because it usually does

not preserve well. The ribs made up 31% of the total faunal remains. They are represented separately in Figure 4.39. They are distributed across the East Block, but are highly concentrated in the same areas as the fauna in general. Since ribs need to be disarticulated from the skeleton to remove the meat, it makes sense to see a large number spread throughout the site.

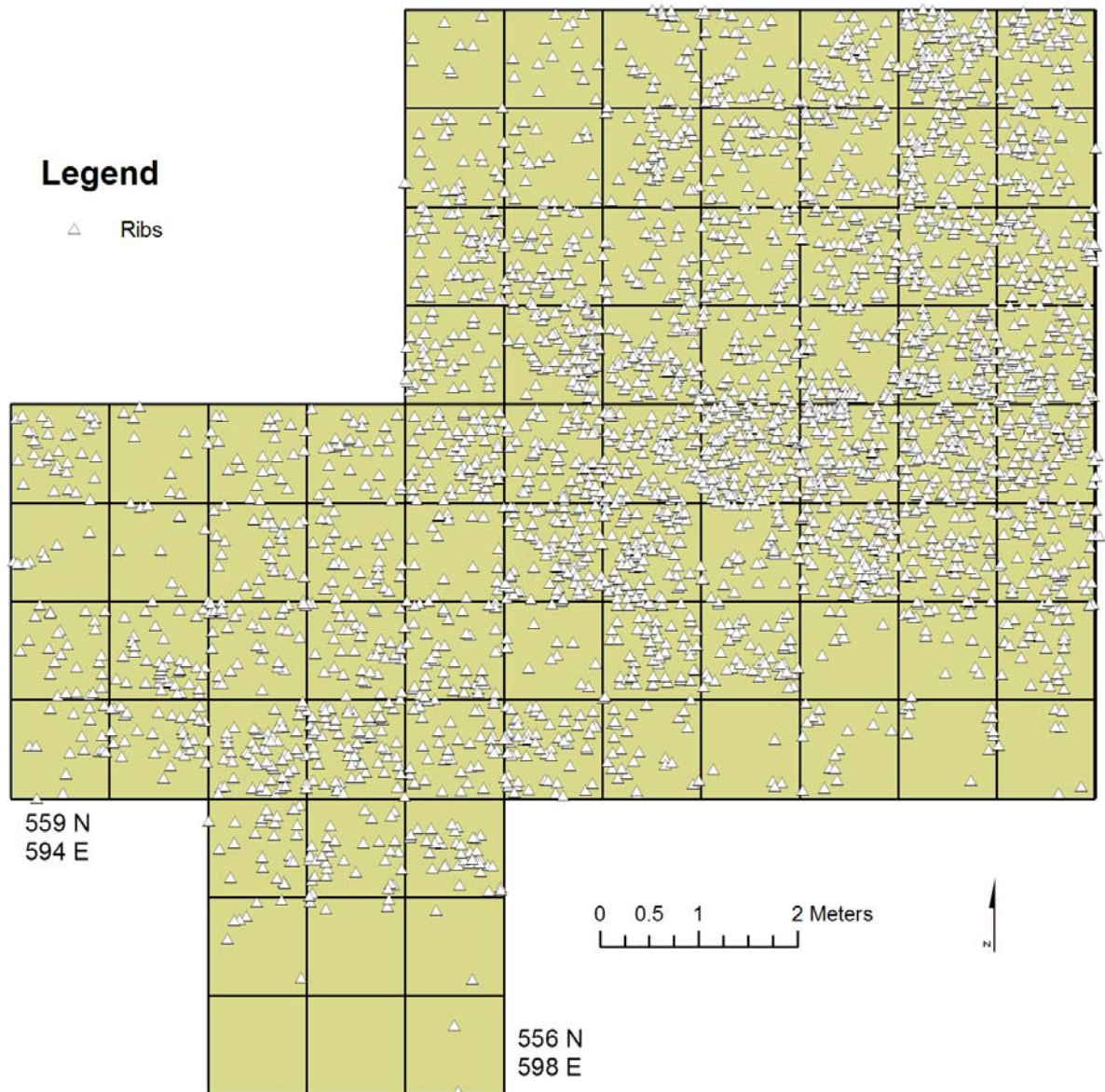


Figure 4.39: The location of the rib fragments found in the East Block.

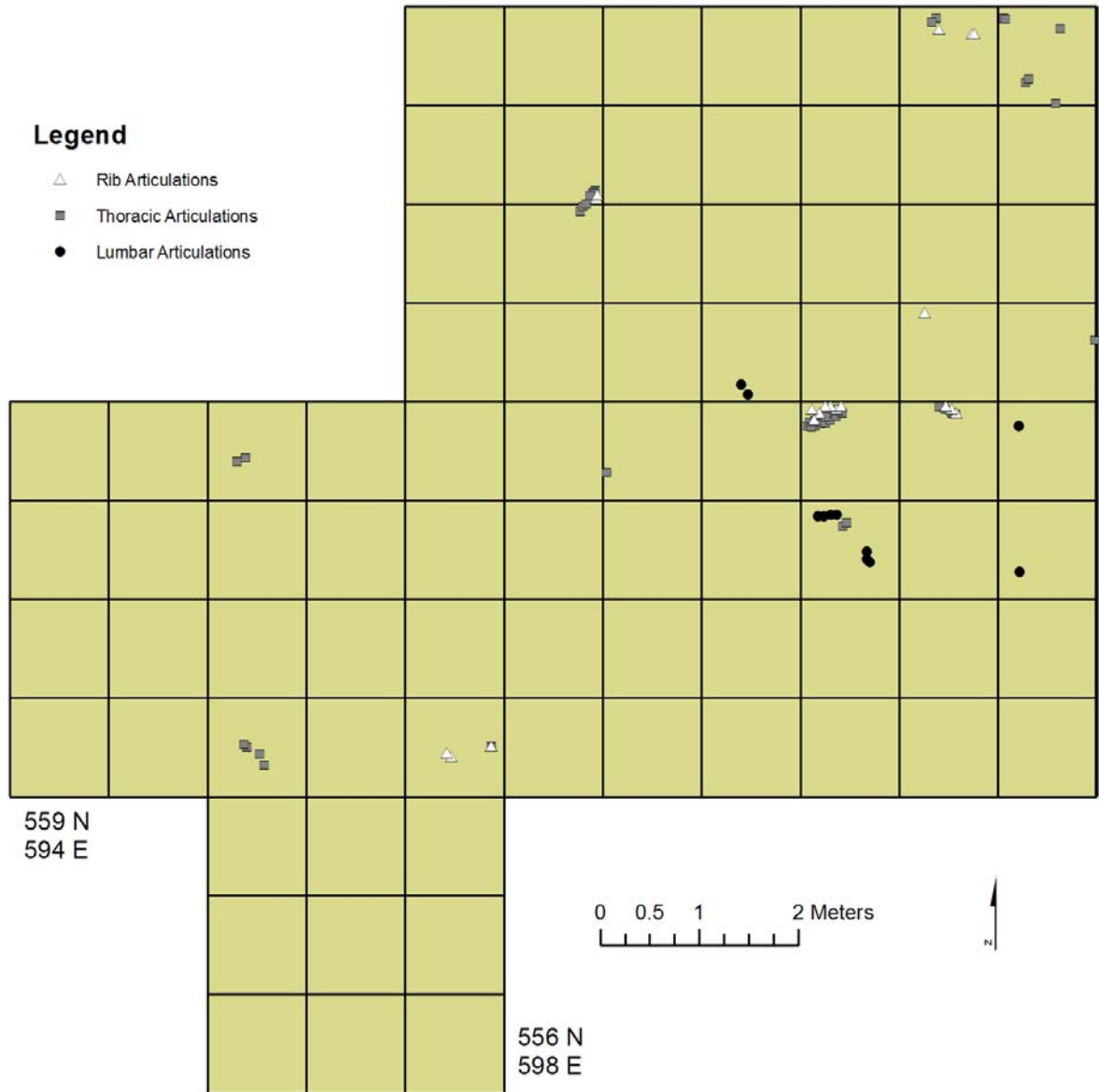


Figure 4.40: The location of rib, thoracic and lumbar vertebrae articulations found in the East Block.

There were a number of articulated core elements. Generally, articulations are seen when sections of the carcass are not processed. These often include portions of the animal that do not have a lot of meat (e.g., the lower limbs) or if meat selection (over kill) occurred. Figure 4.40 displays where the rib, thoracic and lumbar vertebrae articulations were located in the East Block. The presence of these articulations suggests that some

meat selection occurred and that these particular remains were not processed for meat removal.

The next group of faunal remains examined was the long bones, including the tibia, femur, humerus, radius, ulna and long bone fragments (LBFs). The LBFs are pieces of long bone that were not identifiable to a specific long bone (e.g., tibia, femur, humerus, etc.) element. They represent 10% of the total faunal assemblage, while the rest of the identifiable long bones each represent about 1%. As seen in Figure 4.41, the long bones were scattered across the East Block. The large number of LBFs found in the East Block suggests that the long bones were smashed open to get at the marrow, and/or broken into smaller pieces and boiled for grease. They reflect secondary butchering activities. There is a slightly higher concentration along the very east border of the block, especially in unit 562 N 604 E, which may be where marrow extraction, and/or grease rendering took place.

The lower limb group was made up of all elements below the long bones and including the tarsals and carpals. Twenty-three elements, representing 25% of the total faunal assemblage from the East Block, were placed into this group for analysis. Figure 4.42 displays the distribution of the lower limb elements, including those that were articulated, as well as the navicular cuboids used for the MNI.

Like the previously discussed groups, the lower limbs followed the same general trend of the fauna. The articulations was spatially interesting because they reflect primary butchering that involved the separation of these portions of the animal which were not further processed for meat or grease.

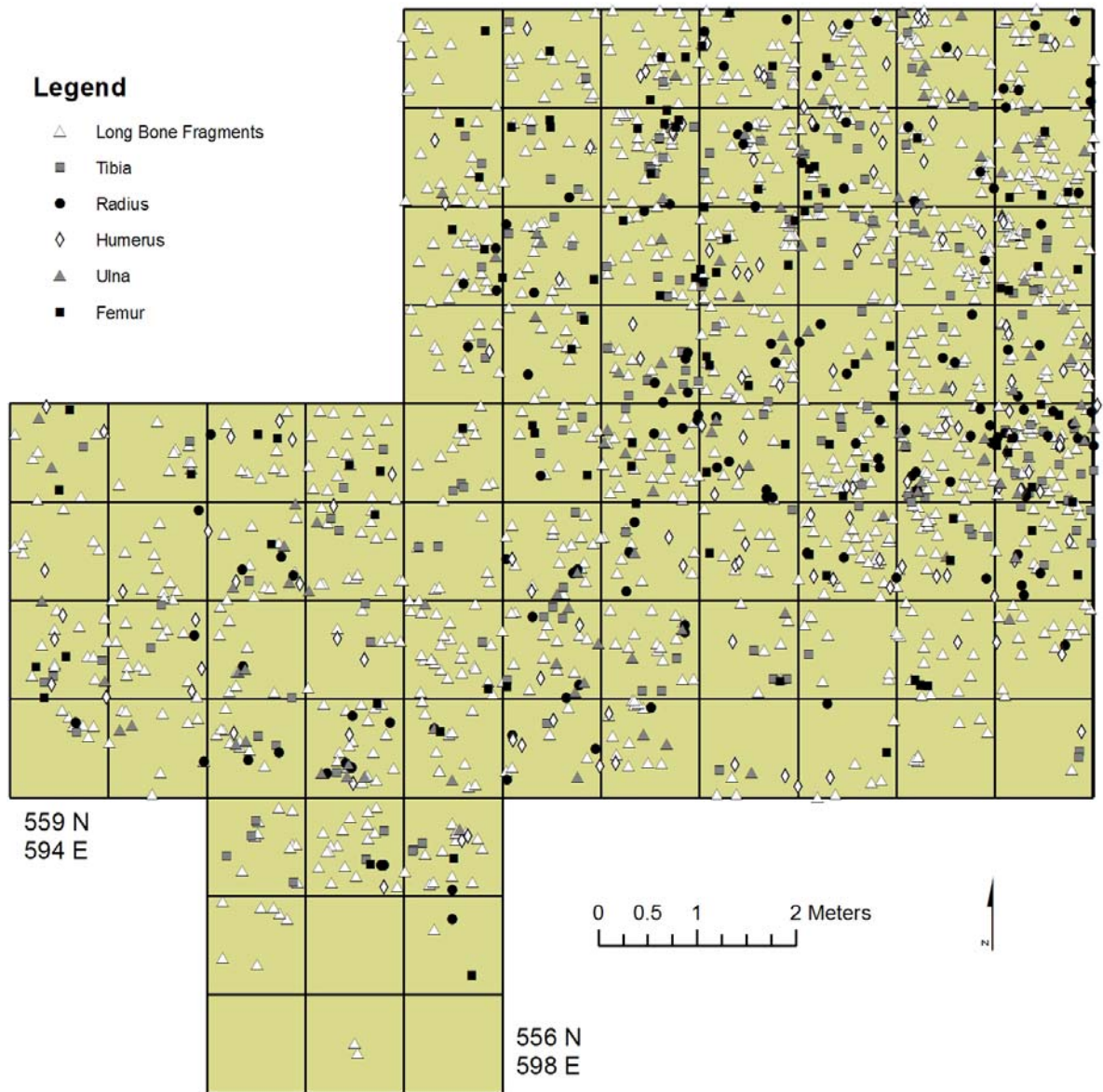


Figure 4.41: The location of the long bones found in the East Block.

The last group examined included the scapula, caudal vertebrae, pelvis and sacrum. These elements were placed in a group together because they represented only a small portion of the total fauna. The scapula represented 3% of the total faunal assemblage, while the caudal vertebrae represent 1%. The pelvis and sacrum together make up less than 1% of the total faunal remains.

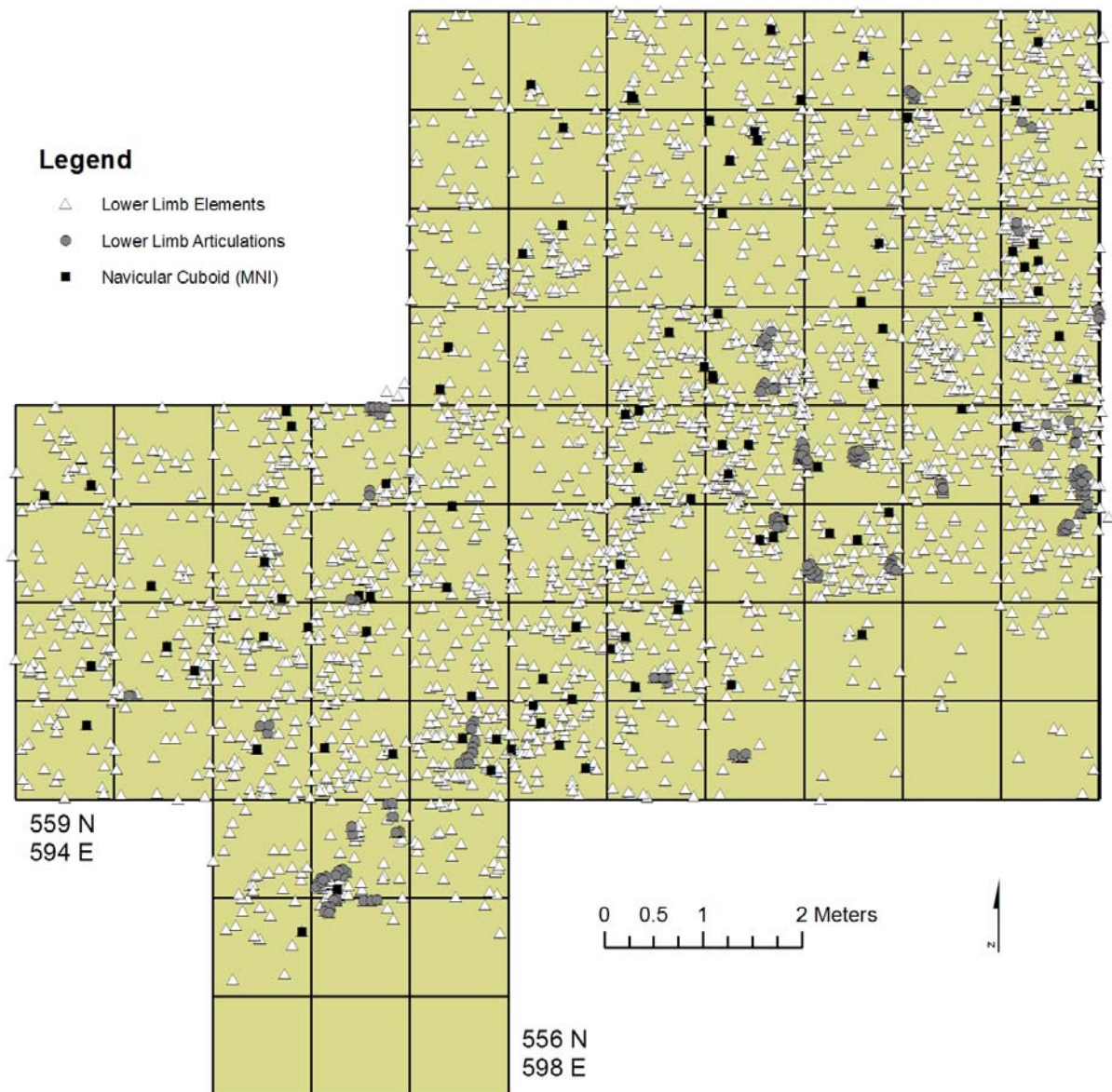


Figure 4.42: The location of the lower limb elements in the East Block. The navicular cuboid was used to calculate the minimum number of individuals (MNI) found at the site. Articulations can also be seen.

Figure 4.43 displays the location of these elements. The scapula, pelvis and sacrum are scattered throughout the East Block. The caudal vertebrae (the tail of the bison) were the only element group that seemed to have a clustered spatial pattern. The majority of the caudal vertebrae were located in units to the south and north, diagonally spread from southwest to the northeast. When the hide of the animal was removed, the

tail was usually removed with it and transported away from the site for hide processing or ceremonial purposes (Shortt 1993: 95; Hjermsstad 1996: 189). Their presence at the Fincastle Site may be because the hides were left at the site or that the tails were removed from the hides and discarded. Since hides do not normally preserve in the archaeological record, differentiating between these two hypotheses is not possible.

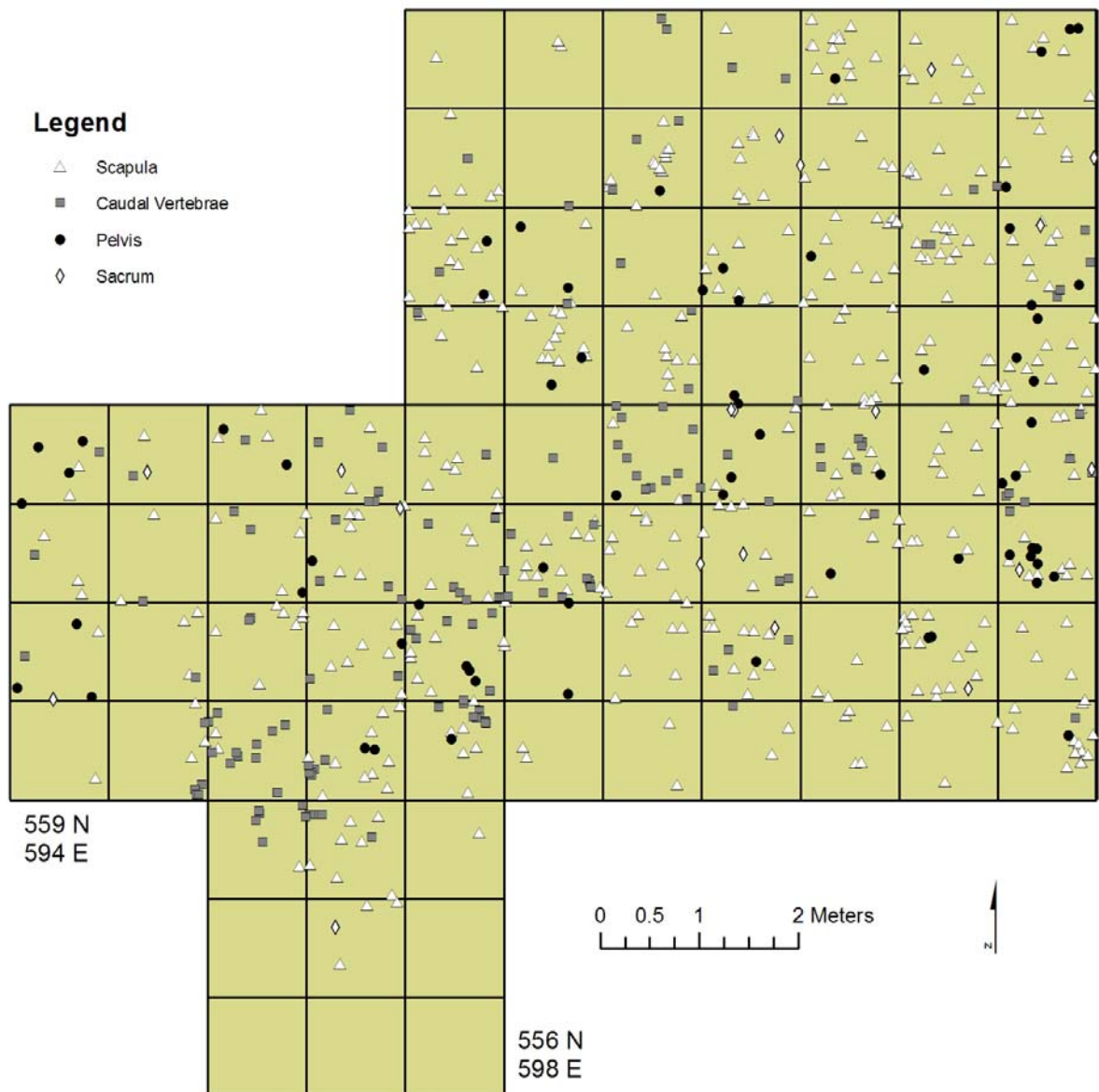


Figure 4.43: The location of the scapula, caudal vertebrae, pelvis and sacrum elements found in the East Block.

Both primary and secondary butchering activities were evident at the Fincastle Site. Butchering breaks and articulations denoted primary butchering activities as the bison was being disarticulated for meat removal. Articulations represent 2% of the total faunal remains. Three percent of the total faunal assemblage from the East Block had direct butchering evidence (i.e., impact marks or fracturing features). Cut marks, presumably made during meat removal, were present on less than 1% of the faunal remains but this may be a factor of preservation. Secondary butchering activities, grease and marrow extraction, were linked to less than 1% of the remains and the burnt remains themselves represent close to 1% of the faunal assemblage.

Figure 4.44 displays the location of the elements with direct processing features together with the lithic tools. Though not many faunal remains are plotted, a few observations can be made. In the northern extension, fewer faunal remains with processing evidence were found when compared to the rest of the East Block. The northern extension was also where the majority of the lithic tools were located. Moreover, secondary processing evidence was more prevalent in the northern part of the site, which was also where more burnt remains were found. This suggests that although primary and secondary processing activities took place across the East Block, lithic tool manufacturing and grease rendering activities were concentrated in the northern part of the block.

The majority of the faunal remains yielding primary butchering evidence were found in the middle section of the East Block. This distribution follows the general trend of the fauna. This spatial distribution suggests that the majority of the processing took place in this area of the site, which also supports the hypothesis that the northern

extension was used primarily for lithic tool manufacture and secondary butchering. That being said, there is evidence for primary and secondary butchering across the East Block, which Kooyman would define as a permeable boundary.

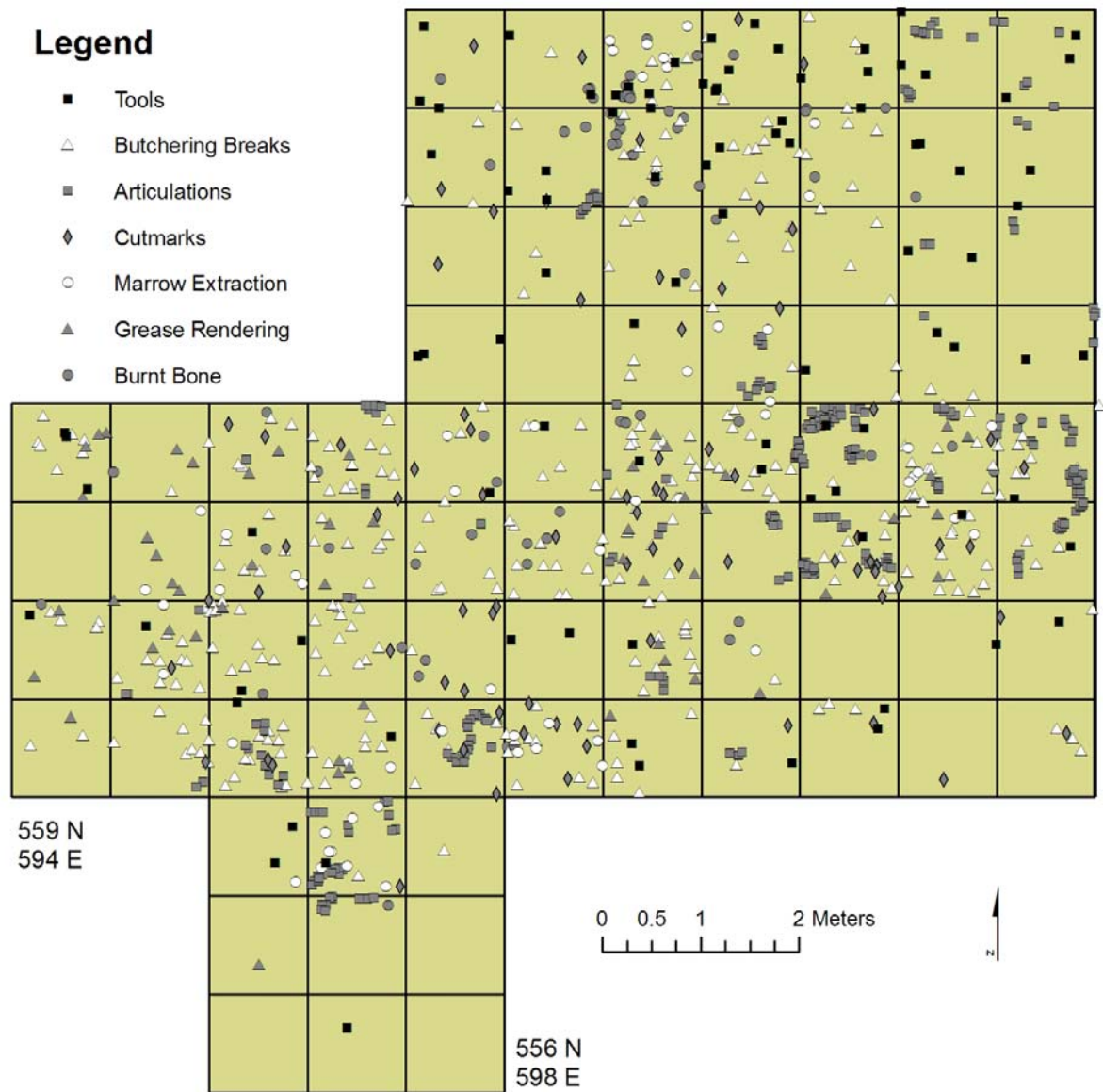


Figure 4.44: The location of the faunal remains with butchering features in the East Block. The lithic tools are also plotted to examine the spatial relationship between these groups of archaeological remains.

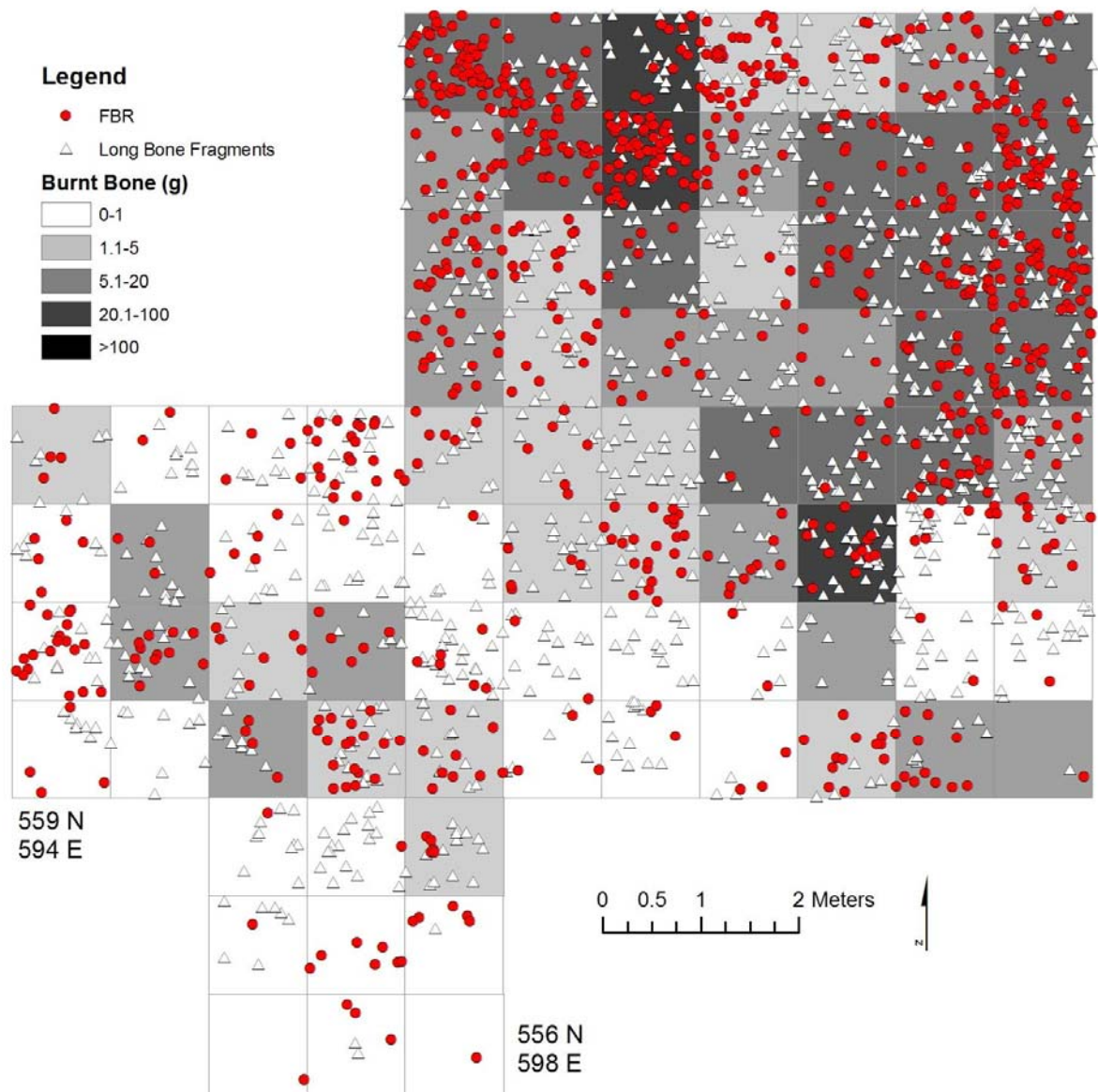


Figure 4.45: The location of the LBFs in relation to the FBR. Weights of burnt bone per square meter are also represented.

The relationship between the long bone fragments and FBR was also studied to detect secondary butchering activities. Long bones contain marrow and were smashed open to remove the higher caloric food source. Bones were also boiled to extract the

grease, which was used to prepare food stores. The bones were smashed into small pieces, boiled and discarded once the grease was rendered.

Long bone fragments were found throughout the site, but the distribution displayed in Figure 4.45 (above) suggests that they were concentrated in the same areas as the FBR. In addition to the LBF and FBR, the weights of burnt bone (sieve and *in situ* pieces) per square meter were spatially examined. The majority of the units in the northern extension of the East Block contained higher weights of burnt bone than other units. These units were also where the highest concentration of FBR was located. Though no formally defined features were found, this suggests that when the LBFs were removed from the boiling pits, they were dumped into the fire and burnt. To confirm this association between the FBR and the LBF, the Pearson's correlation coefficient was used. The output (0.453) validated a positive correlation between the two groups. The same test was carried out for the FBR and burnt bone weights and there also was a positive correlation (0.338).

The burnt bone weights were also compared to the KDE distribution map of the FBR. As seen in Figure 4.46, the quadrat analysis of the burnt bone per square meter corresponds with the distribution of the FBR. High quantities of burnt bone were found in the same areas as the concentrations of FBR. The results from this comparison further validate the hypothesis that secondary butchering activities took place in the northern extension of the East Block.

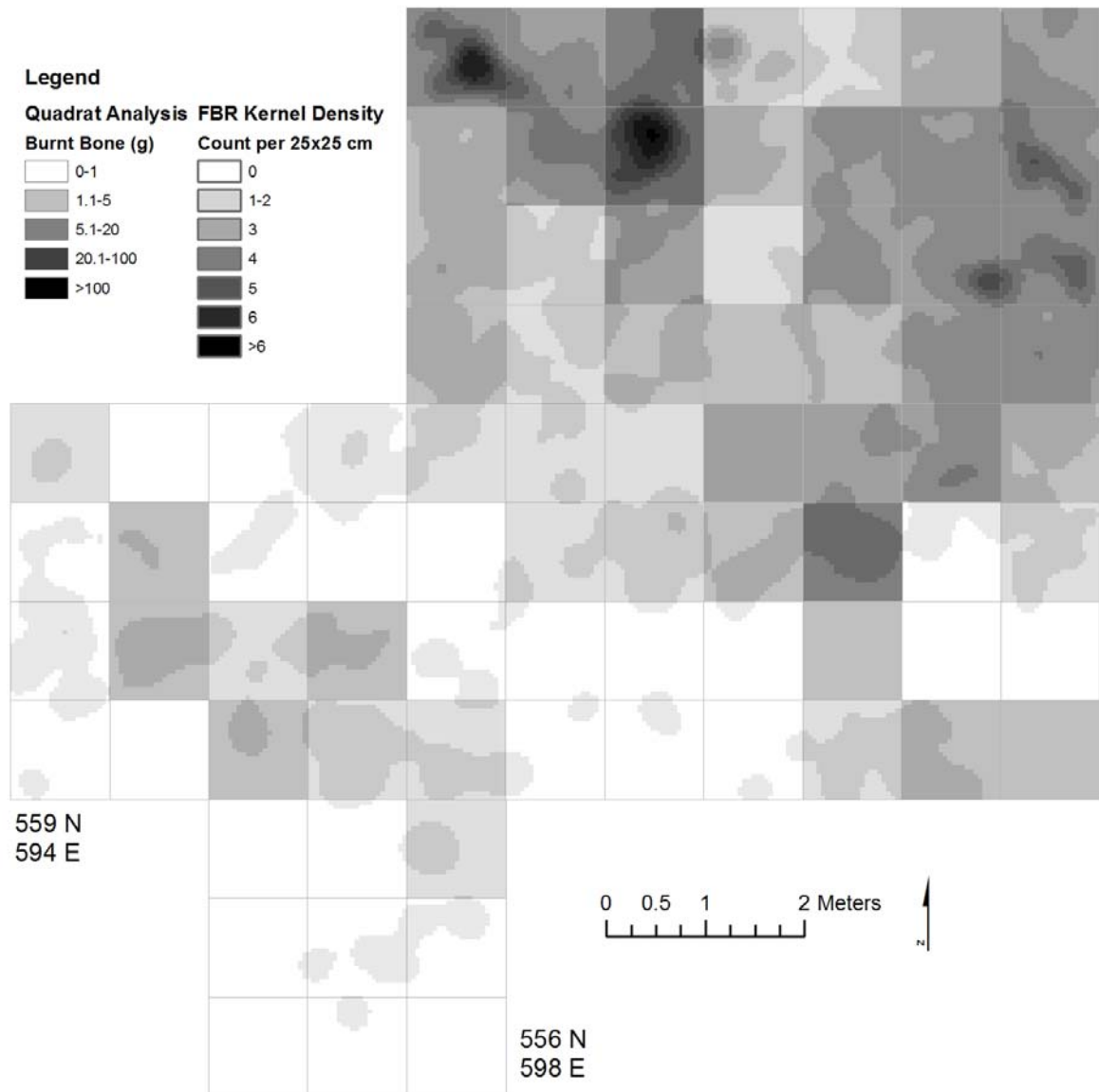


Figure 4.46: The quadrat analysis of the burnt bone weights compared to the KDE distribution map of the FBR.

Though few remains of other species were found at the site, it is interesting to note where they were located. Evidence of canid remains (wolf-sized animals) were found in the West Area and East Block (Figure 4.47). Other species identified include pronghorn, rabbit, bird and small rodents. The remains from the small mammals (rabbit, bird and rodents) most likely postdate the site because they were either found above the

bone bed or in animal burrows that cut into it. The pronghorn remains were found in the bone bed and could have been part of the hunt or were artefacts that were brought in by the hunters. Only four pronghorn bones were recovered, all of which are small complete elements (two lunates, one magnum and one metapodial epiphysis), therefore, further excavations are needed to determine why these bones were present in the bone bed.

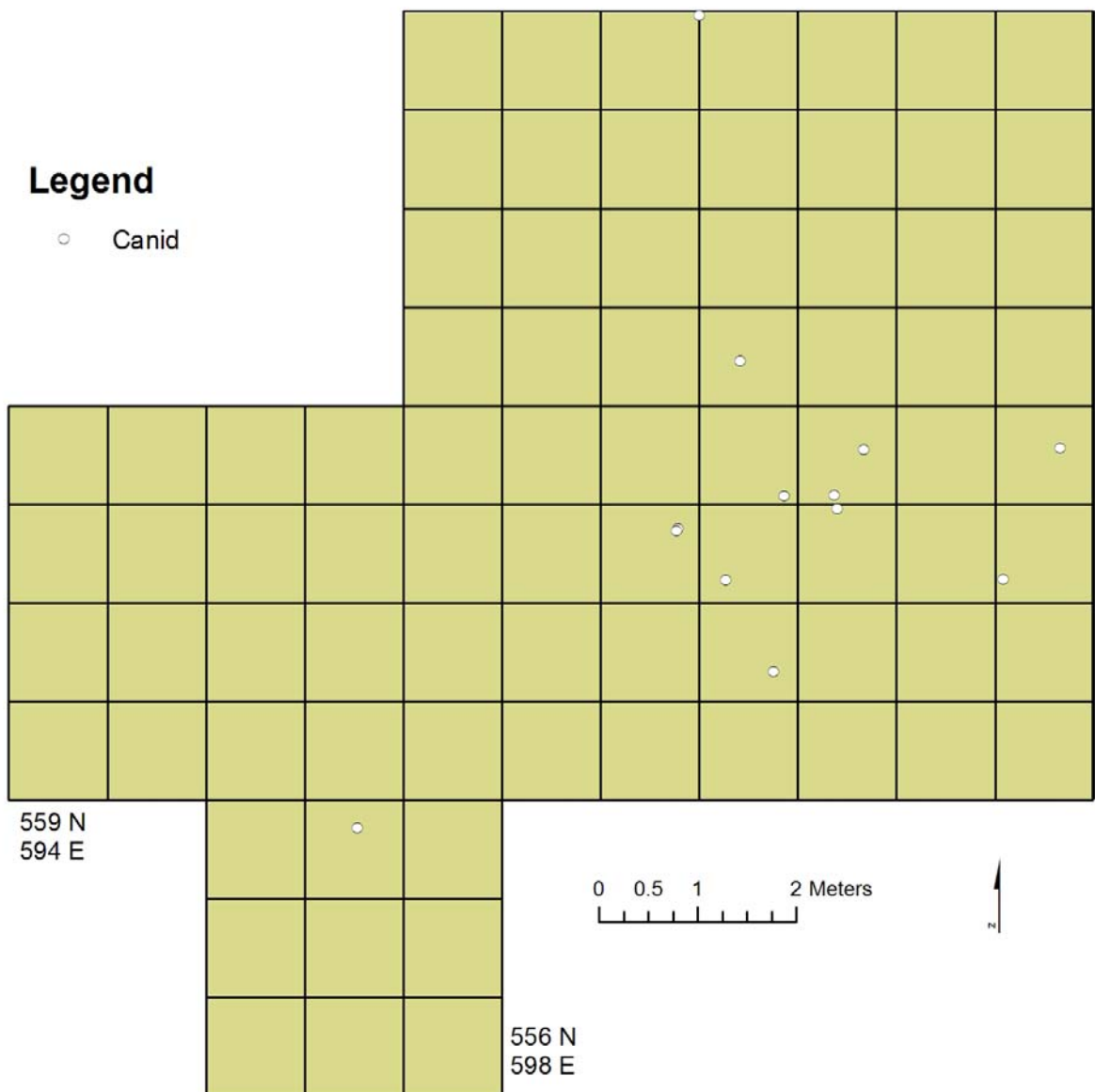


Figure 4.47: The location of the canid remains found in the East Block.

Summary

This chapter explored the ability to visually represent and spatially analyze the Fincastle assemblage in a GIS environment. Since the projectile points and lithic tools were not frequent finds, the data, and therefore the analysis performed, was limited. Valuable information was still obtained, however, through the spatial statistical tests done within the GIS. The results suggest a clustered but weak concentration in the northern extension of the East Block. Studies on the debitage also revealed a concentration, albeit heavier, in the north portion of the excavation block. By looking at all of the debitage queries together (size, flake type, material type, etc.), it was evident that although manufacturing took place across the site, it was more prevalent in the northern extension, and in the Test Pit area. The evidence from all of the lithic remains (projectiles, tools and debitage) together supports the hypothesis that the northern extension of the East Block was the prominent area of lithic manufacture. The analysis of the fire broken rock also revealed higher concentrations in the northern area of the East Block, further validating the hypothesis that cultural activities, other than the kill itself, were more prevalent there.

The faunal remains also yielded interesting results. Because element data could be selected out of the fauna database, studying specific spatial relationships was possible. The lower limb group, for example, evidenced primary butchering because many of the lower limbs were in articulation. The spatial analysis pointed to a concentration of these remains in the centre of the East Block. Secondary butchering was also evident at the site. Because there was a high number of long bone fragments recovered during the excavation, it was assumed that marrow extraction and grease rendering occurred at the site. This assumption was supported when the LBFs were displayed with the FBR and

burnt bone weights. Through the interpretation of the distribution maps, primary butchering activities were noted as being more prevalent in one area of the site, the centre of the East Block, while secondary butchering activities took place in the northern extension of the East Block, the same area that lithic manufacture was more prominent. In summary, when the archaeological remains were examined using distribution maps and spatial statistics, particular cultural activities seemed to be present in certain areas of the site.

Based on the results presented in this chapter, using a GIS to spatially analyze archaeological data is clearly beneficial. The GIS was able to store, query and spatially analyze complex archaeological data. Spatial patterns that were not visible by observation alone were detected. The dense concentrations of fauna, which limited the visual spatial analysis, were easily examined using the GIS. Moreover, when spatial analyses were carried out using the GIS, primary and secondary butchering areas were noted. This chapter only explored a few of the spatial analytical tests that could be carried out on the data from the Fincastle Kill Site. Many more cultural observations can be made from continued analysis.

Chapter 5 – Conclusion

Research Summary

Spatially analyzing the archaeological record is an important part of site interpretation. As reviewed in Chapter 2, a number of different statistical tests are used in archaeology, most of which are now available in a Geographic Information System (GIS). A GIS is able to output distribution maps, as well as calculate spatial statistics. GIS techniques have been employed in archaeological projects, though few scholars have employed it for analyses beyond using the mapping functions.

The number of archaeological remains recovered from the meticulously recorded excavations at the Fincastle Bison Kill Site provided a large data set to explore spatial analysis within a GIS. Though some cultural interpretations based on the spatial statistical tests carried out were made, the goal of this thesis was to assess the capabilities of using a Geographical Information System to analyze large quantities of archaeological data.

Using a GIS to calculate the statistics and display distribution maps was relatively quick and easy, however, entering the data was a time consuming process. This research project began with the digitization of each archaeological remain into the GIS. These remains retained their own spatial data, which were needed to display the plotted remains and use the spatial statistical methods to detect spatial patterns.

The steps involved in creating the GIS databases were straightforward. The five different types of remains from the Fincastle Site were input into the GIS (projectile points, lithic tools, debitage, FBR and fauna). Once all of the data were entered, the analysis of the archaeological remains was limited only by time and enquiry. General plot

maps displaying the spatial location of each type of remain were generated for the three areas of the site, but this research focused on the East Block because there was a larger horizontal area to work with.

The data from each type of archaeological remain were run through the nearest neighbour, Moran's I, Getis-Ord General G_i^* and Ripley's K statistical tests to determine if the distributions were clustered, regular or random. The results from these tests confirmed that all of the archaeological remains had a clustered distribution, some exhibiting stronger patterns than others. For those groups that had a large data set to work with, quadrat analysis and kernel density estimation (KDE) were also carried out. These analysis methods are difficult to perform on limited amounts of data because the visual output is not conclusive.

Distribution maps were generated to display the attributes or features of each type of archaeological remain, and to view the distribution of the different remains together. The tests carried out were selected examples used to examine the value of using a GIS. These maps were easy to create and interpret. Those remains originally digitized as polygons provided a good visual representation of the site, which enabled detailed observations to be made.

Not only does the GIS software have the means to display the data visually, the program can be used to run the statistical tests. Having these features in the same program saves the user from having to switch between visual output software and statistical software. This advantage was demonstrated with the quadrat analysis and kernel density estimation results, which gave visual outputs displaying where the archaeological remains were clustered. The limitations of these statistical tests are that

they can only be carried out on large data sets (e.g., debitage, FBR and fauna in this case). Quadrat analysis was easy to perform because the program simply counted the remains per 25x25 cm square and represented the density of remains. However, the visual output was often disjointed and not easily read. On the other hand, the kernel density estimation outputs were easily readable and patterns were more apparent. Having this statistical technique readily available in the GIS is clearly advantageous.

Another valuable feature of the GIS identified through this research is the ability to have each remain represented in a separate layer. This allows the user to view each remain individually or in combination depending on the relationships being studied. It saves the user from having to overlay maps of individual remains in order to view the spatial relationships. This capability was demonstrated several times in Chapter 4. The lithic tools, for example, were viewed individually to interpret their spatial pattern, then viewed in relation to the debitage in order to identify areas of tool manufacture.

With the archaeological remains represented in separate layers, any attribute or combination of attributes can be divided out to study the spatial relationships. All of the bone groupings that were examined, for example, were selected out of the main fauna shapefile according to their element and anatomical position. The same process was applied to the debitage and FBR analyses when material type, size, etc. were studied. Other visual programs do not have this capability; therefore, separate maps would need to be created to show these subsets of the Fincastle assemblage.

Being able to display different layers together and select remains out of the main shapefile according to recorded attributes allow for detailed spatial analysis to be carried out. Figure 4.46, for example, shows the FBR, LBFs and burnt bone weights together on

a map. The FBR is its own shapefile, whereas the LBFs were selected out of the main fauna shapefile. The burnt bone weights were added to the map using the quadrat analysis test. These remains were selected out of the data three different ways and displayed on a map together.

These are just a few examples that show how using a GIS can assist in the study of the spatial patterns that may have existed at an archaeological site. Though all of the spatial analysis can be done by hand or using basic statistical programs, this study demonstrated the benefits of using a GIS. Though it is time consuming to enter the spatial and attribute data into a format readable in a GIS, the value of this investment is extremely high. Many researchers are now realizing the benefits of using GIS software and plan their projects accordingly. Hopefully, more will embrace the software and take archaeological analysis beyond what is traditionally done.

Future Directions

Since the aim of this thesis was to research an alternative way to spatially interpret site data, future researchers will use the data entered into the GIS to explore deeper cultural aspects of the Fincastle Site. This includes, but is not limited to, further delimiting specific cultural activity areas, such as hearths, boiling pits and tool manufacturing areas. Although these types of activities were examined in this thesis, further investigation, and possible excavation, could be carried out to identify these areas. Examining the platforms, terminations and dorsal scarring of the debitage can give an idea of the reduction strategy, the skill of the flint knapper and possibly their location. To further analyze the butchering activities at the site, the faunal remains could be studied in

conjunction with the lithic tools, as well as the microdebitage in conjunction with scrapers, to determine where they were butchering and re-sharpening their flakes.

Moreover, predictive modeling can be used to denote areas of the site that should be excavated and for different reasons. A model using the faunal elements, for example, may suggest expansion to the east of the East Block. Alternatively, secondary processing likely took place in the elevated areas of the site, therefore, exploring the West Area and north of the Test Pits and East Block should be a priority. Moreover, the high numbers of debitage in the Test Pits suggest a knapping manufacture zone was present in that area.

This research will be applied to future studies of the Fincastle material, but the methodology can also be applied to other sites across the globe. Spatial analysis is the foundation of archaeological interpretation, therefore, using a GIS can only aid in this type of analysis.

Final Conclusions

The goal of this thesis was to examine how Geographic Information software can be used in the spatial analysis of archaeological sites, using the assemblage from the Fincastle Bison Kill Site (DIOx-5). The large horizontal area (the 81 m² East Block), in which a large number of archaeological remains were recovered during the excavations, made this site an ideal test case. Though the cultural interpretation in this thesis was limited to a select group of examples, through the use of a GIS, the spatial distribution of the archaeological remains were easily studied using visual plots and statistical tests.

The statistical methods that are frequently used in the discipline of archaeology, such as quadrat analysis and the nearest neighbour method, are available in ArcGIS. Since these methods do not take into account all of the spatial information, they should

only be used in conjunction with the other statistical tests (kernel density estimation, Ripley's K, Moran's I and Getis-Ord General G_i).

Kernel density estimation gives a visual output, like quadrat analysis, but this technique incorporates the distance between points in all directions. Therefore, it is a better technique to apply to archaeological data because it studies the spatial relationships between the remains. The nearest neighbour method takes into account the distance between remains, but only to the nearest neighbour no matter the direction it is in. Using techniques, such as the Moran's I and Getis-Ord General G_i statistical methods, will give a better understanding of the actual distribution because they use a defined distance around the points. The Ripley's K method offers another way to explore the degree of clustering over many distance bands, which is beneficial when trying to determine the optimal resolution for the distribution. Though the quadrat analysis and the nearest neighbour method are less conclusive than the tests listed above, they still need to be calculated in order to compare new results to previous archaeological analysis.

An archaeologist has a responsibility to interpret the archaeological data using the best methods available. The better the spatial analysis, the more robust the archaeological interpretation is. This means using the GIS technology to interpret our cultural heritage. This thesis has established that though the investments required to use a GIS are significant, the value of this technology is exceptional.

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