CATALOGUING IN A DIGITAL AGE:

THE APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS TO LARGE-SCALE INTRA-SITE ANALYSIS OF ARTIFACT DATA AT GAULT, TEXAS

A Thesis

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By

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ABSTRACT

I will explore how Geographic Information Systems can be applied to a large body of disjointed archaeological data. The efficacy of this software is tested using the artifact information collected by on- going research at the Gault site. Using GIS, I will attempt to unify the multiple datasets created by various projects at the Gault School of Archaeological Research into a single uniform system. Utilizing GIS databases as the central cataloguing system at an archaeological site, not only creates a uniform system in which data is stored, but promotes future research. I will use the case study of searching for anthropogenic patterns or clusters in the spatial relationships among artifacts at the Gault site, to better understand the practical applications of GIS as a cataloguing system. The resulting project will serve as an example of how archaeologists at sites, which have been excavated over long periods of time and through many methodological changes, can unify and organize their data in a way that will promote future research.

BIOGRAPHICAL SKETCH

Bonnie began her career in archaeology at Johns Hopkins University, where she gained dual Bachelor of Arts degrees in Archaeology and Classical Studies. While there, she earned departmental honors through a project to create a predictive analysis of shipwrecks for archaeological investigation along the Alaska coastline, completed in conjunction with the Alaska Office of History and Archaeology. Bonnie began gaining field experience in the summer of 2012, as a student at the Poggio Civitate archaeological site in Tuscany, Italy, where she returned for 2 more years as supervisory staff. During this time, Bonnie gained additional field experience as a volunteer at the Coriglia excavations, in Umbria, Italy.

Upon completion of her Bachelor's degree, Bonnie entered the Masters program in the Cornell Institute of Archaeology and Material Sciences. This thesis is the result of her work towards a Master of Art's degree in Archaeology, with a focus on American studies. While writing her thesis, Bonnie also worked in the field of Cultural Resource Management, working as an archaeology technician for SWCA Environmental Consultants, on projects in Colorado, Wyoming, North Dakota, Texas, and Oklahoma. In August 2016, Bonnie will begin her doctoral studies at Southern Methodist University.

Thank you to my mother and father,

who made me strong enough to overcome any obstacle.

ACKNOWLEDGEMENTS

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GIS – Geographic Information Systems

CATALOGUING IN A DIGITAL AGE:

THE APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS TO LARGE-SCALE INTRA-SITE ANALYSIS OF ARTIFACT DATA AT GAULT, TEXAS

Thirteen-thousand years ago, a group of people wandered in to a small valley, in what would eventually become Central Texas. In this valley they found everything they needed to survive. With high limestone hills, containing the chert needed for tools, a clear river running nearby, for water, and rich soil that grew a wide variety of plants, this valley would prove to be a perfect place to live. Over the millennia, though the occupants changed, each new group found these same advantages and continued to build their homes at the Gault site.

Scientists have long been fascinated by this valley that held the perfect confluence of circumstances to house the earliest people of this continent. In 1929, the first archaeologist in Texas, J. E. Pearce, began attempting to find artifacts indicative of early populations in this area through excavation. The site became known by the name Gault, for Henry Gault, the owner of the land at the time excavations began (Gault School of Archaeology, 2011).

In the intervening decades of research, archaeologists have uncovered over 2 million artifacts, dating as far back as 12,500 BC. The problem, however, is that as each excavation took place, unique methods for recording and cataloguing findings were utilized, resulting in a large backlog of data, which has not been coordinated. Though a great deal of research has been done using small sections of data from this larger collection of available artifacts, there has been no coalescing of these projects into a single database for analysis. In order to maintain continuity of artifact identification, I will be working with all artifacts which have been catalogued and digitized by a member of the *Gault School for Archaeological Research,* to make a comprehensive database of these artifacts.

Through this thesis, I will explore how Geographic Information Systems (GIS) can be applied to a large body of disjointed data, which I will then apply to the on-going research at the Gault site. Using GIS, I will attempt to unify this dataset into a single uniform system. I will be testing the future usability of this GIS storage methodology by searching for anthropogenic patterns or clusters in the spatial relationships among artifacts at the Gault site. The resulting project will serve as an example of how archaeologists at sites, which have been excavated over long periods of time and through many methodological changes, can unify and organize their data in a way that will promote future research.

A History of GIS and its Uses in Archaeology

Before GIS can be applied to the accumulation of artifacts at the Gault site, it is important to know about the technology itself, and how it is being used in the field of archaeology. I will provide an overview of how Geographic Information Systems have evolved. Using this knowledge it will be possible to see how modern archaeologists are employing this technology to benefit their current excavations. By exploring the concepts of GIS, it will be possible to create my own research parameters for data at the Gault site.

Geographic Information Systems (GIS) may be best recognized as the latest development in complex map creation and analysis, so in a sense the history of GIS is one that can be traced back for centuries, even to the invention of maps (Harley, 1989). For the purpose of this study, I will be looking at the period in history when these maps went from a paper-based study to an integrated system of technologies to collect, store, and analyze geographic based data (McCoy and Lagenfoged 2009). I will provide a working definition of GIS, followed by the history of its use within related fields, and finally the beneficial and problematic ways it is being used archaeology, before ultimately applying this technology to the Gault site.

Though the technology of digitally mapping coordinate systems was in existence as early as the 1960s (Richards 1998), the term GIS was not coined until 1991, when Michael Goodchild published a paper about this technology and the impacts it would have in the future. In that paper, he argues that the term 'Geographic Information Systems' was not broad enough to cover the wide range of possibilities available from this new technology. In contrast, he proposed that 'Geographic Information Science' might better represent the unique characteristics of spatial data and the problems that arise in its analysis (Schuurman 2008). The difference, he believed, was based in the conceptual models being created, which were affected by the representations of data from the three-dimensional surface of the Earth to the two-dimensional maps that have been standard for centuries, and the translation of these maps into computer systems. For the purposes of this discussion, however, and in keeping with the wider use of the label, I will use the term Geographic Information Systems (GIS) as well.

GIS, in itself, does not represent the end-product of a combined study of computer science and cartography, however, merely a convergence of the available technologies into a broader and more intricate way of representing geographical data (Harris and Lock, 2006). Examining the parts that make up this whole will help to convey the possibilities. The hardware on which GIS depends includes Global Positioning Systems (GPS), Laser maps, and Geophysical survey (McCoy and Lagenfoged 2009). These are the technologies that allow for the collection of coordinates in a unified system that will then be used to create accurate maps. Part of the importance of data collection at this level comes from the need to correct the distortions caused by displaying data from a three-dimensional surface onto a two dimensional representation. This is where the basic terrain images are developed, on which other collected data can be displayed. The software that then manages and combines these data consists of many different products from a competitive market, including full Geographic Information Systems, such as Esri's ArcGIS, image analysis programs, such as ERDAS Imagine, computer aided drawing suites, such as AutoCAD or Adobe Illustrator, and programs to handle data point coordinates, vector files, and raster images, such as Microsoft Excel (McCoy and Lagenfoged 2009). The large number of both public and private software packages that can be used to analyze coordinate data electronically is part of what creates the need for such a broad definition of Geographic Information Systems.

The attribute table is the most revolutionary concept in Geographic Information Systems. Maps have always been able to answer the rudimentary questions of 'where', but the attributes brought into GIS software programs allow many more questions to be asked and answered. An attribute table stores all of the information tied to that coordinate, including site or artifact descriptions, dates, and supplementary sources for research (Taylor 1991). This allows for the combination of both quantitative and qualitative data, which can be manipulated and appreciated as they relate geographically. For example, in the attribute table I have created for the Gault Site one projectile point is recorded using the latitude (959.53), the longitude (950.63), and the elevation (96.64), which constitute the quantitative data, but it is also identified as a 'projectile point', in the 'Clovis' time period, excavated by 'Brigham Young University', which constitutes some of the qualitative data available. With more developed attribute tables, qualitative data such as pictures and relevant article links can also be included. This provides a single location in which all forms of information regarding each artifact can be easily located within the ArcGIS program.

In many ways, the advent of GIS has been a beneficial change to the way in which archaeological data is observed. It allows researchers to gather and analyze more complete records of an area, through access to larger data sets, along with a variety of images and models used to display that information (McCoy 2009). The records produced in GIS also account for much of the complexity in the data produced in social science studies, because they often rely on large amounts of data that correlate in many different ways that must be in some way fused together (Torrens 2010). Geography is an easily grasped way to place a set of data into a context for analysis. Part of the process for analysis, however, comes with a debate of what theoretical ideologies are being utilized. When it was first created, many geographers and social scientists worried that GIS would bring about a renewed emphasis on positivism (Elvin, 2009) and strictly scientific modeling (Schuurman 2000). It appears that the way in which people have interpreted the information and patterns or clusters indicative of human activities apparent in maps is more aligned with the theoretical ideologies they used to interpret their data in other circumstances (Schuurman 2000). Despite the fact that GIS is not really a new technology, the constantly developing and changing nature of its uses leaves a great amount of room for innovations.

Archaeology is a field of study which uses coordinate-based data frequently, so the integration of Geographic Information Systems (GIS) into regularly used systems of analysis has been undertaken since its development in the 1960s. Maps and cartography are tools long used by archaeologists to produce visual representations of archaeological sites, providing ways of recognizing anthropogenic patterns or clusters of artifacts that would otherwise be overlooked (Connolly and Lake, 2006). These maps in their paper form, however, cannot be easily manipulated, edited, or compared, limiting their utility in data analysis. The manipulation of a set of sites can include changing the subset being examined, the way sites are represented in an image, or the ways in which these sites are grouped. With each new perspective, new anthropogenic patterns or clusters appear. These anthropogenic patterns or clusters of artifacts can then be compared to the historical and material record being uncovered in the excavation process.

Data gathered in the course of archaeological research are directly tied, not only to a site, but also to an exact location within a site by recording the location of objects in relation to a site datum, the main coordinate from which all other recordings are based. Therefore, GIS can be used to enhance research at multiple levels, including identifying patterns indicative of human activity in the distributions of sites and objects, the existence of these anthropogenic patterns or clusters of artifacts in other locations, and the way these patterns or clusters of artifacts change over-time (Aldenderfer, 1998). This research, however, is limited by the availability of data amenable to use in GIS, and the ability of excavations to gather and record new data that are suitable for GIS use.

It is my intention to create an attribute table, made up of the accumulated artifact information provided in the Gault catalogues. I will then upload this attribute table into Geographic Information Systems Software. Once there, I will be able to search for patterns in the spatial distribution of artifacts at the Gault site.

A Case Study: Artifact Clustering at Gault, Texas

In 2006, *The Gault School of Archaeological Research* was created as a non-profit private organization to provide uniform inquiry and protection of the Gault site as well as research and education regarding the earliest peoples in the Americas (Gault School of Archaeology, 2011). In order to comprehend the type of data that has been collected for this thesis, I will provide a historical overview of the Gault Site. By describing the environment from which the artifacts came, and the ways in which they were excavated, I will be able to provide a more complete picture of the data that comes from this long-term archaeological site.

Due to its specific environmental location, the Gault site has been re-occupied for long periods of time over many millennia. It sits in a small valley of limestone hills, where multiple streams are interwoven, having carved their way through the surrounding hills. To the West, South, and East of the excavation areas are large plateaus of limestone that characterize much of West and Southern Texas (Hilderbrand, et al., 1978), while to the East of the Gault Site is the Black Prairie, full of the famously rich, black clay soils that make modern Texas farmers so successful (Texas beyond History, 2001). This variable and fertile valley seems to be a precise and unique confluence of circumstances that would have been especially hospitable for early populations.

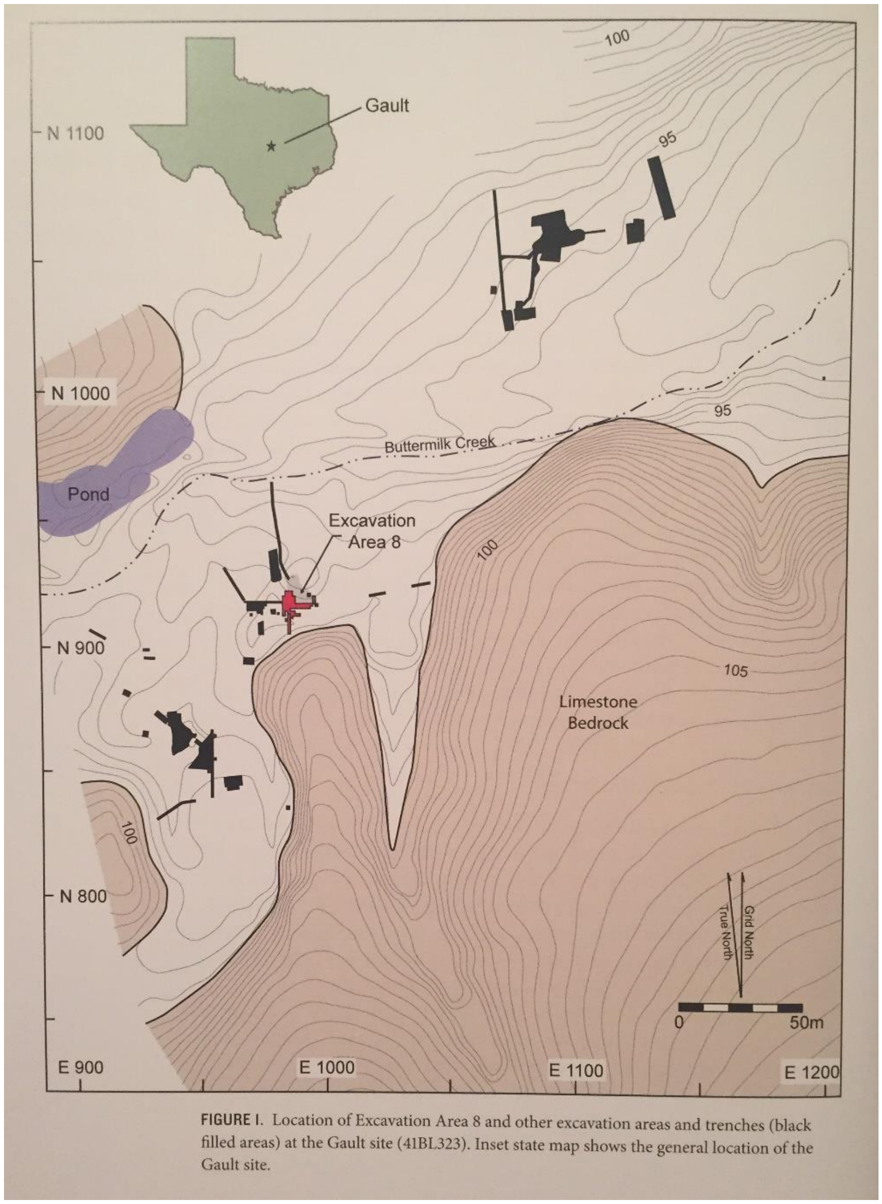

FIGURE I. Location of Excavation Area 8 and other excavation areas and trenches (black filled areas) at the Gault site (41BL323). Inset state map shows the general location of the Gault site.

Figure 1 – Map of the Gault Site from David Carlson's book, 'Clovis Lithic Technology: An Investigation of a Stratified Workshop at the Gault Site, Texas'

It is possible to see in Figure 1, the limited space within the entirety of the Gault valley that has been excavated (ca. 3% of the 16 hectare site), and the general location of excavated areas within the topography of the larger Gault site. This excavated area, indicated by the thick black filled and red filled spaces on the map, is located in the low points of this river valley, less than 50 meters from Buttermilk Creek, which runs East to West, through the center of the excavations.

The methodology that I am using to analyze this site is derived from a very simple assumption that has been frequently discussed elsewhere in the literature on the expansion of the Americas (Field, et al., 2007). My assumption being that the various groups who inhabited the Gault Site, throughout all of the time periods, utilized or were familiar with the materials present at this location. Thus the types of artifacts present and the way they were left will be indicative of a purposeful placement by an inhabitant of Gault into that location.

During the century of excavations, cultural deposits ranging from a few centimeters to over three meters in thickness have been discovered (Carlson, 2011). Through these excavations, 3 distinct cultural periods of occupation have been identified in the artifacts that have been collected1: the late prehistoric period, 1,200-400 bp, the archaic period, 9,000-1,200 bp; and the paleoindian period, 10,000-9,000 bp (Collins, 2003). Though the late prehistoric and archaic periods have been heavily disturbed by farming, looting, and collecting in some areas, the paleoindian strata offer virtually undisturbed contexts. It is within this classification that evidence of Clovis materials, dating from 10,900- 9,000 bp, have been identified, with the possibility of containing pre-Clovis material (Wernecke and Collins, 2010). The theory being currently pursued by many of the archaeologists examining this site is that Gault was continually occupied by a number of societies for domestic purposes from approximately 13,000 bp to the present (Carlson, 2011).

Such large and well-preserved sites are not common, so Gault provides an important opportunity for a variety of research questions. One of the significant benefits of the Gault Site is that so much of its stratigraphy has remained intact and each time period has been definitively identified using characteristic artifacts, such as Clovis points in the paleoindian strata, as well as absolute dating methods such as 14C and OSL. Thus, when looking for spatial patterns and relationships among various artifacts, it is possible to assume that the picture being produced is in fact, a fairly accurate portrayal of the layer as it was created.

For the purposes of this thesis I have been granted access to the records of recovered artifacts at the Gault site by The Gault School of Archaeological Research. Each of the excavations since 1929 have produced their own records and record keeping systems, nearly half of which were produced before computers were common tools in archaeological excavations, and nearly all of which have selected different formats for their cataloguing of artifacts. This discordance among records is a commonplace problem that many old sites face. The scholars at the Gault School of Archaeological Research have begun to address the problem of research variability, simply by creating an organization through which all scholarly work will be conducted, providing unified methodology for future excavation and unified procedures for identification of past discoveries.

From this collection of just over 2 million artifacts, I found 47,749 artifacts which have been fully identified by members of the *Gault School for Archaeological Research* to include the exact coordinates of a point provenience, including depth, and a laboratory identification of the artifact itself. These artifacts come from field school excavations by Brigham Young University, the University of Texas at Austin, Texas A&M University, the University of Exeter, the Texas Archeological Society, and private collectors, completed between the years 1929 and 2008. Using this catalogue, I can create a complete visual representation of the Gault site, as it has been excavated thus far. The result of which is an analysis of all cultural remains, searching for distribution patterns or clusters of artifacts that could be indicative of human activity, among three artifact types (lithic scatter, bone, and tools).

When selecting data for this project, I required that each artifact have at least an associated identification and coordinate information. This is the bare minimum necessary to build an attribute table in GIS programs for an archaeological site. I required that each data point have an artifact identification to allow for better grouping of the artifact types together, which will allow for pattern analysis. The coordinate data is necessary because without it, that artifact cannot be mapped, and thus this software is not particularly useful. This is an important limitation to the GIS software to note, because there are many factors which can limit the availability of coordinate data at an archaeological site.

Though I was provided with digitized records relating to 2 million artifacts, only 47,749 artifacts had both an identification and coordinate information. While this is a small percentage of the available artifacts, it is important to realize that the Gault School for Archaeological Research is working with artifacts collected by dozens of excavators, over the course of 70 years. During this time archaeological methodologies have changed, which can effect not only the coordinate information collected, but also the identification of artifacts both in the field and in the laboratory. The data collected can also be effected by the professionalism of an excavation. It also takes a lot of time and funding to identify artifacts and connect those artifacts to available paperwork, which can severely limit the data available for examination at any given time, especially when considering the 2 million artifacts being recorded at the Gault site.

Paleoindian lithic scatter accounted for 34,617 (72%) of the artifacts with which I was working, the most commonly identified artifacts within this category were angular chert, debitage, flakes, and modified flakes. Paleoindian faunal remains accounted for 4,069 (8%) of the artifacts with which I was working, the most commonly identified artifacts within this category were animal bone and burned animal bone. Paleoindian tools accounted for 3,965 (8%) of the artifacts with which I was working, the most commonly identified artifacts within this category were biface fragments, blade fragments, and projectile points. Archaic lithic scatter accounted for 2,413 (5%) of the artifacts with which I was working, the most commonly identified artifacts within this category were angular chert and debitage. Archaic faunal remains accounted for 265 (less than 1%) of the artifacts with which I was working, the most commonly identified artifacts within this category were bone and burned bone. Archaic tools accounted for 923 (1%) of the artifacts with which I was working, the most commonly identified artifacts within this category were bifaces and biface fragments. Late Prehistoric lithic scatter accounted for 1,026 (2%) of the artifacts with which I was working, the most commonly identified of which were angular chert and debitage. Late Prehistoric bones accounted for 217 (less than 1%) of the artifacts with which I was working, the most commonly identified of which were bone and burned bone. Late Prehistoric tools accounted for 254 (less than 1%) of the artifacts with which I was working, the most commonly identified of which were biface fragments and blade fragments. These categories were created using the artifact identifications digitized in various excel spreadsheets, I did not examine these artifacts myself. Future work, however, would benefit from a single categorization system, which would allow for more intricate categories.

The first step in creating a system, in which Geographic Information Systems software can be used with the data at the Gault Site, was to create a unified attribute table. This attribute table consisted of all artifacts uncovered at Gault since the first excavation in 1929. The challenge I faced in creating this attribute table centers around the fact that there have been many changes in the recording methods at the Gault site over nearly a century of excavation. This problem, however, is also the reason I have selected GIS as the software in which to create a cataloguing system for the Gault Site. The attribute table of GIS will provide the most substantial storage system of data, including photographic, maps, and links to research.

The information necessary to create this attribute table was previously located in a series of Excel, Text documents, and storage files that have been digitized by various participants in the Gault School for Archaeological Research. I chose a Microsoft Excel document in which to record my attribute table. My efforts were focused on collecting the disparate digital records that had been gathered by other students and interns who were granted access to the artifact collections. While this is the most time-consuming part of the GIS analysis process, data collection and organization still requires manual organization.

The GIS software I used to manipulate my attribute table is ArcGIS produced by ESRI. This is the program taught at most universities, copies of which are also provided in a free trial period by ESRI. This program supplies predefined map templates that have global coordinate systems built in to the software, so that when new localized coordinates are added, they are automatically registered in relation to the global coordinate system in the map. There are other options, including open-source and online software which follow the same properties as ArcGIS, and can be interchangeable for this selection.

To correct for the distortion of projecting a sphere on to a two-dimensional form, there are different templates that allow for distortions along different axes. Depending on the space in which one focuses, there can be distortion laterally or vertically for large scales and minimal distortion along smaller areas. The Gault site is such a confined area that there is little distortion along the surface of the Earth, so it was not a factor in choosing my coordinate projection system. I therefore selected WGS1984, as this is the most common projection system registered by handheld devices.

After importing an excel table into the ArcGIS software and displaying it on the mapping screen it is possible to employ a large variety of applications and queries to analyze the data spatially. This is also the step where the vector and raster data produced by other projects can be collected to create a more complete map, including environmental or remote sensing data collection. This ease of trying different element selections and parameters is a major benefit of Geographic Information Systems. It can be used at varying scales, and it can be manipulated easily. GIS can also handle large amounts of data, both alphabetic and numeric storage systems. The data can also be accessed on an individual level by either actively clicking on a point, or by searching the attribute tables. By collecting all of the various data analysis types into one standardized system then displaying it in a format where the analyses can be visualized together, provides a more complete context for each subsequent excavator.

To demonstrate how a site, in which multiple data sets have been organized into a single GIS display, can then use that organization to produce further analysis, I created a series of analysis, searching for overall patterns in the artifact distribution. The first map I produced was a display of all the data (47,749 artifacts) for which full information was available (Figure 2). One of the limitations in working with a site that has a backlog of millions of artifacts is that you must have the time and resources to properly catalog and digitize your interpretations. The Gault School of Archaeological Research provides an overarching interpretive framework, under which all artifacts are analyzed. This unified interpretation method means that all artifacts will be identified in the same way, making these results comparable. I only worked with 47,749 artifacts, of the over 2 million found since 1929, because not all artifacts excavated have been identified and catalogued. I began my work with the data from Gault by producing a map which included all artifacts that had been identified and included their location information.

I analyzed this display of all 47,749 artifacts, by sorting the artifacts into the time periods to which they each belonged. The Gault School of Archaeological Research identified three time periods as cultural groupings within the 14,500 years of occupation at the Gault Site: late prehistoric, archaic, and paleoindian (older-than-Clovis was defined at a later date)(Collins, 2003). These three categories applied the third dimension of time to the artifacts being discussed. These three maps show the distribution of artifacts within each of the three specific time periods identified.

Figure 2 – Site Overview

When reading figures 2-8, it is important to note that the area portrayed is the entirety of the Gault Site, not all of which has been excavated. This means that what appears to be a high density area of artifacts in the North East and South West section of the maps, are actually the excavated areas, and the spaces between them are unexcavated areas. When looking across the entirety of the site, it is important to note that only 2% of the estimated area of Gault has been excavated, so where no excavation has taken place will have no artifacts located in the map. In figures 9-11, a zoomed in view of the South West high density area, it is possible to see that what appears to be a large number of artifacts created by prehistoric clustering, is actually a result of excavation. This is made more obvious by the linear nature and right angles which define the clustered area boundaries. It is not possible to do a density analysis, because we are working with a very skewed data sample, where the only representation of the site have been arbitrarily selected by archaeologists, not dictated by prehistoric actions. Therefore, what appears to be a clustering of artifacts created by prehistoric occupation is actually a display of an arbitrary excavated area, where artifacts were uncovered by archaeologists.

This thesis is focused on the uses of Geographic Information Systems in organizing data across and archaeological site. At the Gault Site, I used this technology to create a database before testing it by searching for anthropogenic patterns or clustering. The artifacts do not tend to be grouped into distinct patterns, but instead are distributed over the entirety of the excavated area. The lithics for all periods of the Gault site were located between latitudes 852-1,246 and longitudes 776-1400, the bones were located between latitudes 911-1204 and longitudes 887-1314, the tools were located between latitudes 789-1300 and longitudes 752-1562. No patterning was apparent in Figure 2, which shows all artifacts across the excavated area. Figures 3-5, in which the artifacts are separated based on the time periods in which they were discarded, show the same random dispersal. Thus far, the entirety of the excavated area of the Gault Site appeared to show no patterns of artifact distribution through space and time.

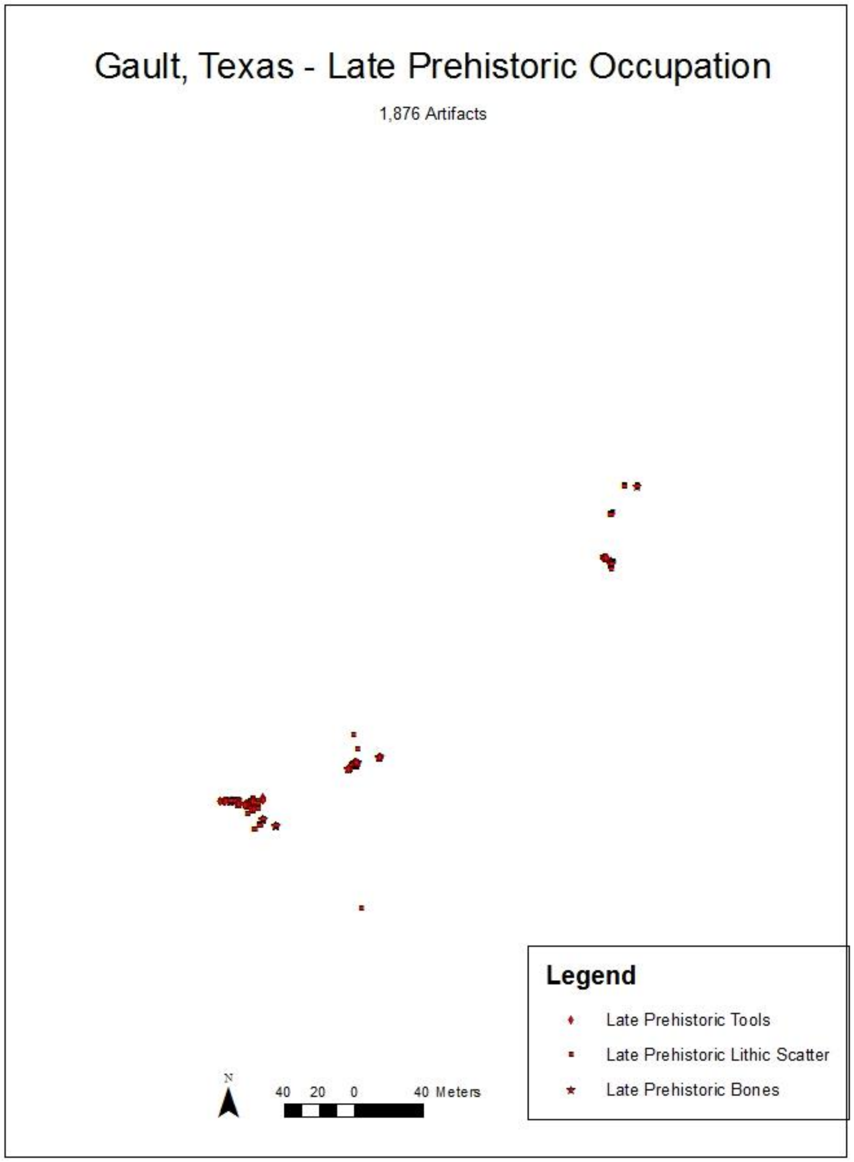

Figure 3 – Map of Gault Late Prehistoric Occupation

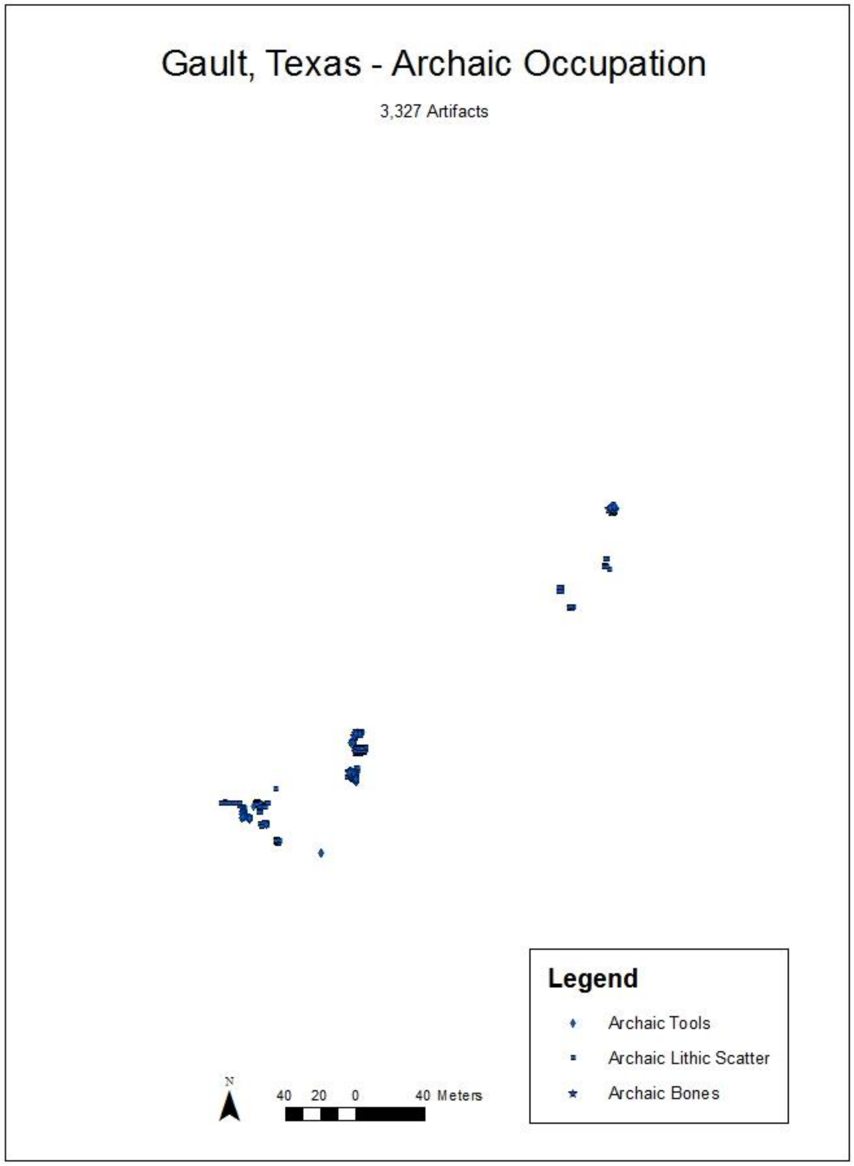

Figure 4 – Map of Gault Archaic Occupation

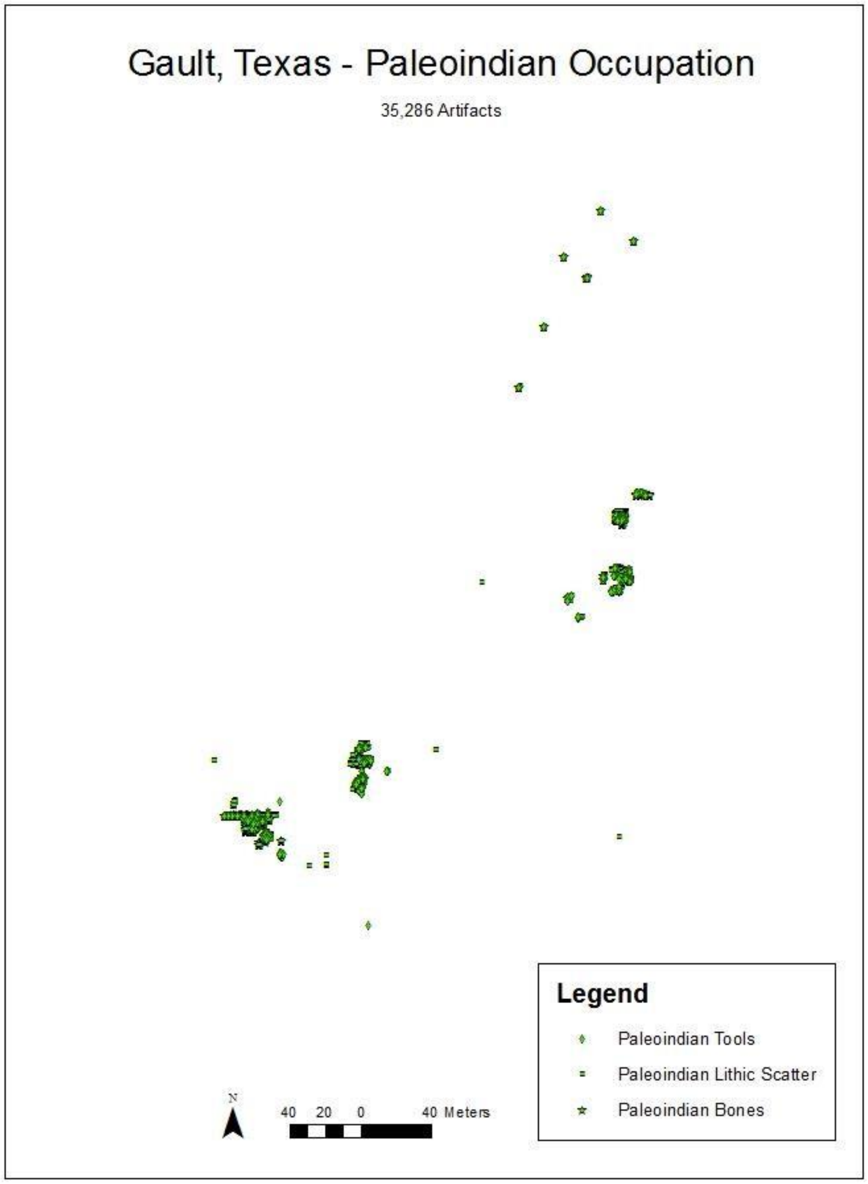

Figure 5 – Map of Gault Paleoindian Occupation

I decided to begin searching different types of artifacts to see if there was clustering based on the way items were used, because I had not discerned any patterns or clusters when looking at the artifacts as a total, nor when they were divided by time. My assumption being that the activities during which an item was used may have determined where that artifact ended up within the site.

I chose to complete an analysis based on artifact use by creating a query for the types of artifacts identified within each layer. I selected as my focus the three most commonly identified types of artifacts: tools, lithic scatter, and bone (See Figures 6-8). From these maps, however, we can see that these artifacts still occupy the entirety of the excavated area with no clustering by type.

When reading the maps I produced for this project, it is important to note that the images represent 47,000 points across a very small area. Thus a map representing the entirety of the excavated areas of Gault, will have hundreds of artifact points stacked one on top of the other. The computer software is able to discriminate between each artifact's coordinates, but the software cannot create visual discrimination between two points in such close proximity. Software, like ArcGIS, however, is not intended to just create the final images of a map, but to provide a platform for various forms of analysis; it is this analytical process that is the focus of this thesis.

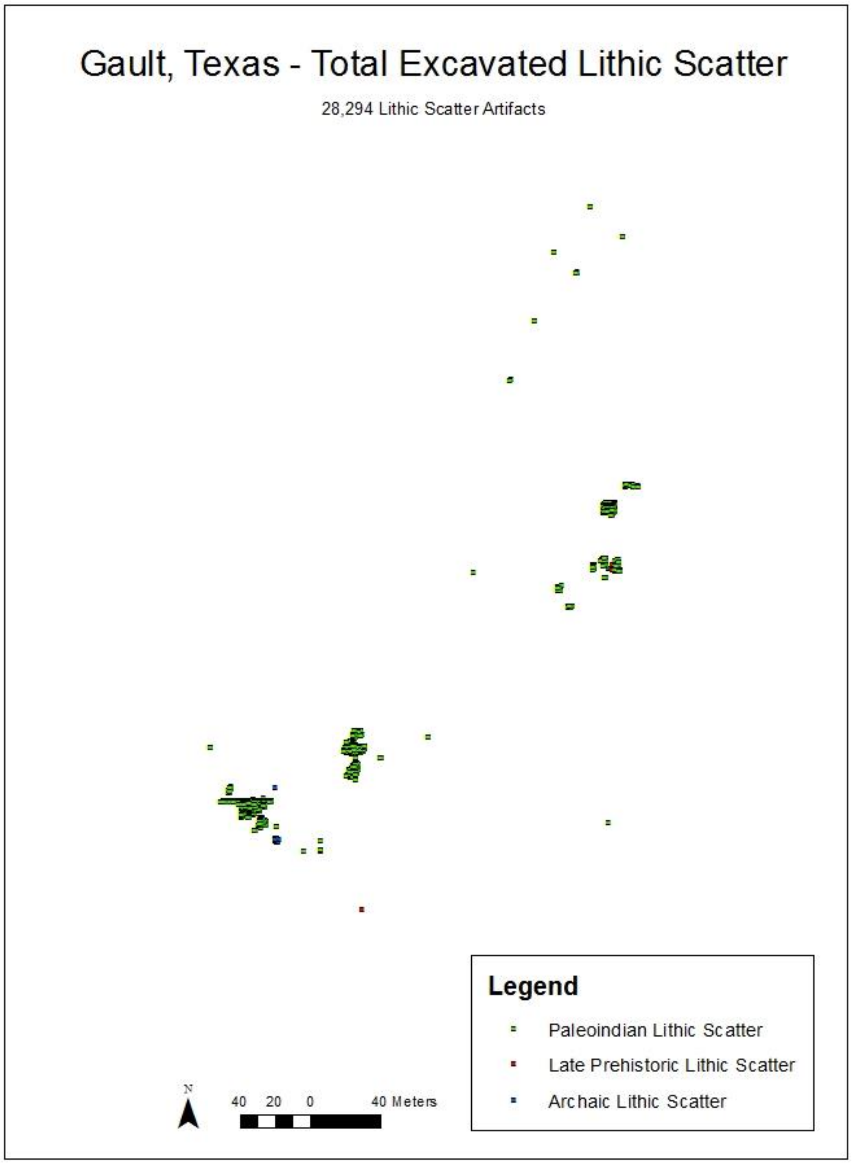

Figure 6 – Map of Gault Lithic Scatter

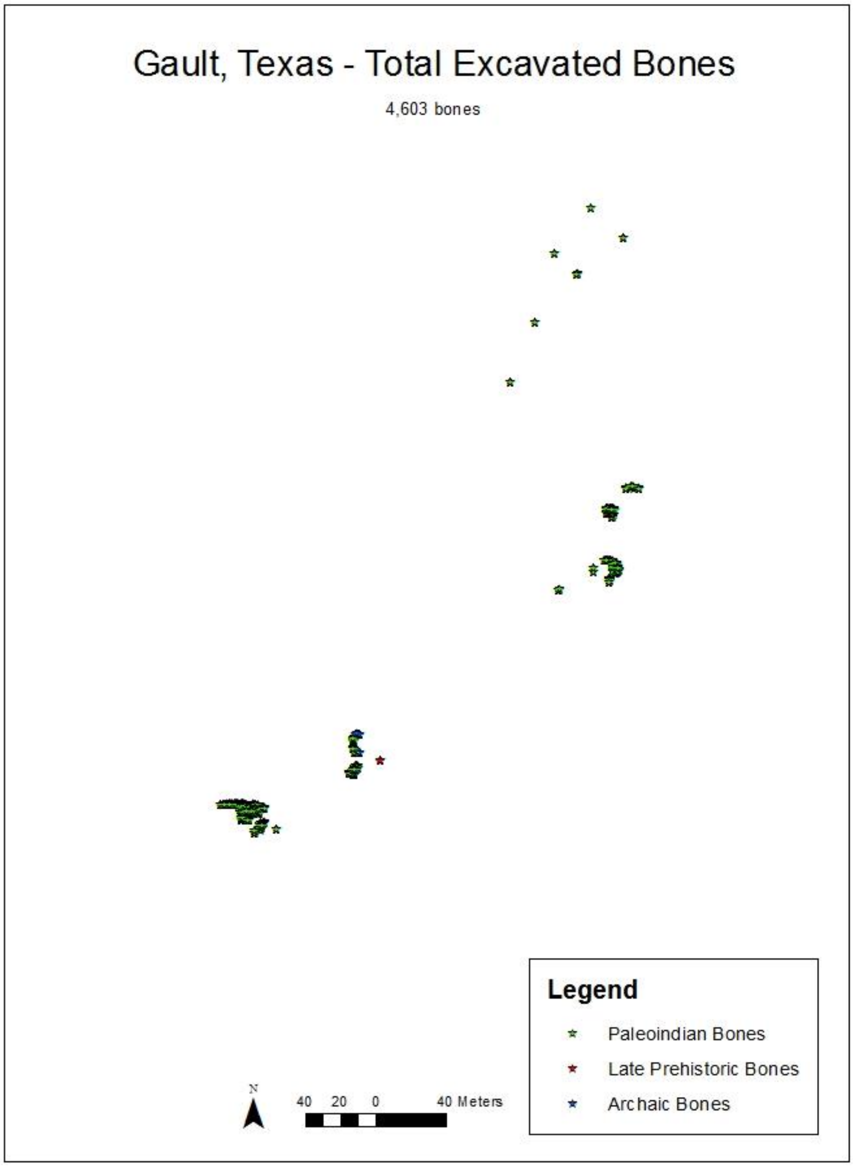

Figure 7 – Map of Gault Bones

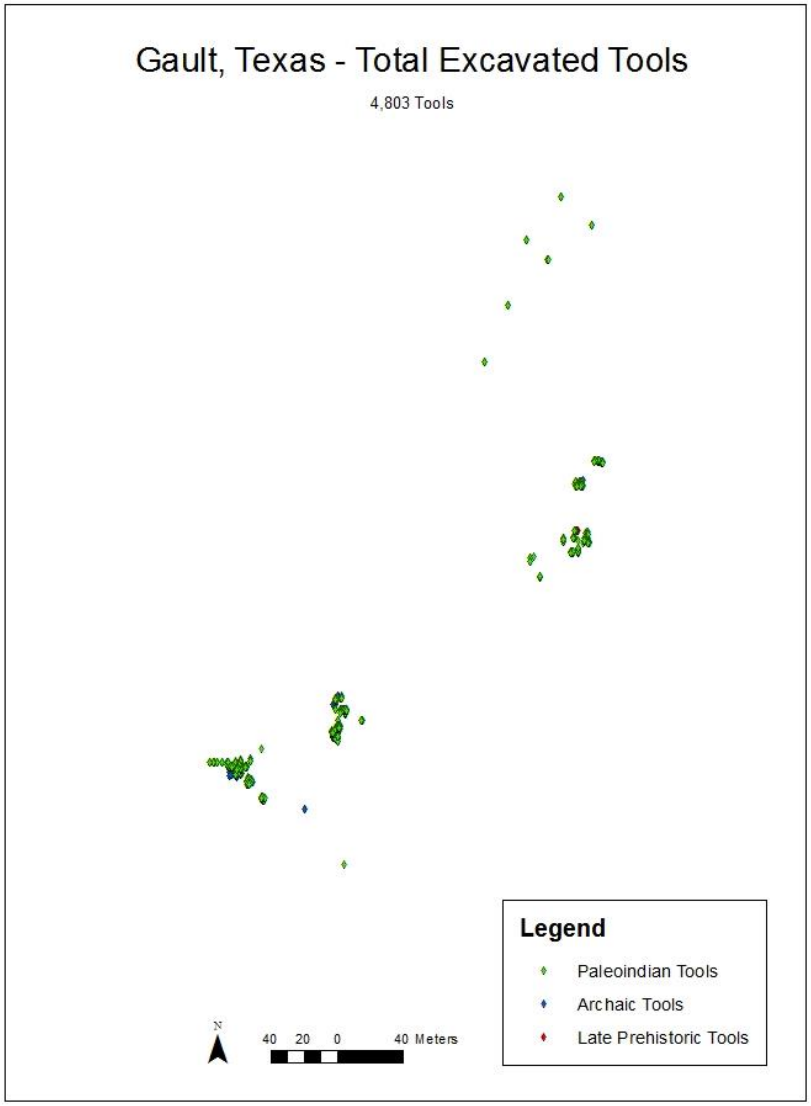

Figure 8 – Map of Gault Tools

To further search for patterns I examined the Paleoindian period, analyzing a high-density artifact distribution area for clustering at a finer resolution for each artifact type. I chose the paleoindian period for three main reasons: it is an undisturbed context, it is one of the largest collection of data which provides for a more complete analysis, and it provides insight into one of the main excavation questions at the Gault School. Figure 9 shows the zoomed in section of the site, to demonstrate from where these maps have been selected. When looking at this figure, it is important to note that there is a large portion of this area which has been excavated, which will allow for a more complete picture of what human actions occurred in the area. In figures 10-12 I have created a finer resolution analysis of what would visually appear to be a clustering of artifacts within the Gault Site. In examining the data over a space of a few meters, as opposed to the hectares of information provided in previous maps, it is possible to see that the first patterns visible are in fact individual excavation units. Looking at figures 9-11, the straight lines of artifact distribution are indicative of the boundaries of excavation units, which are done in series of units and trenches. While it is possible to see in figure 11 that there are excavation units, in a North-South transect along the middle of the area, with a higher concentration of bone, lithic scatter, and tool remains than other areas in the site.

Figure 10 represents the Paleoindian lithic scatter within the zoomed-in area, which accounts for the largest percentage of available data at the Gault Site. In my analysis, I used the boundaries of these artifact locations to establish the units where archaeologists were excavating, with the assumption that places where the bones or tools did not have an equal distribution, a pattern may emerge. The artifacts in the previously identified transect account for 60% of the total artifacts within the zoomed-in area, but only 2% of the entirety of the Paleolithic artifacts at the Gault Site. In figure 11, this transect looks like a high density area of faunal remains, but it accounts for only 20% of the faunal remains in this area. Which emphasizes the fact that visual analysis is not enough to identify patterns when doing archaeological analyses. In figure 12, I compared this same transect looking for a patterning of tools. The tools showed a high incidence along the same transect, but instead of a solid line, the bones showed higher frequencies in separated squares. When doing an analysis of this area, there appears to be transect in which 60% of the tools and lithics of this zoomed in area are located. The rectilinear nature of these areas indicate a strong relation to archaeological excavation units.

The differences in frequency of tools and lithic scatter could be related to two main possibilities. The first possibility is a misidentification in the field or laboratory, however, this area was all excavated by one program, thus it is unlikely. The second possibility is that this area was indeed a paleoindian activity area. Given the high density of lithics and tools, in the same area, this could be tool workshop, which would leave full and partial tools, as well as the materials from that process. I created the categories of lithic scatter and tools based on the category names provided in previously digitized documents, however, future research would need to determine more accurate categories for artifact storage, meaning that before a definitive conclusion can be made about a type of activity space, it would be necessary to use a definitive and standardized definition of both tool and lithic scatter. Demonstrating that while GIS is an important tool, the person using it should be able to appropriately analyze the data with which they are working. It is also important to note that this area may be indicating the boundary of a Paleolithic activity area.

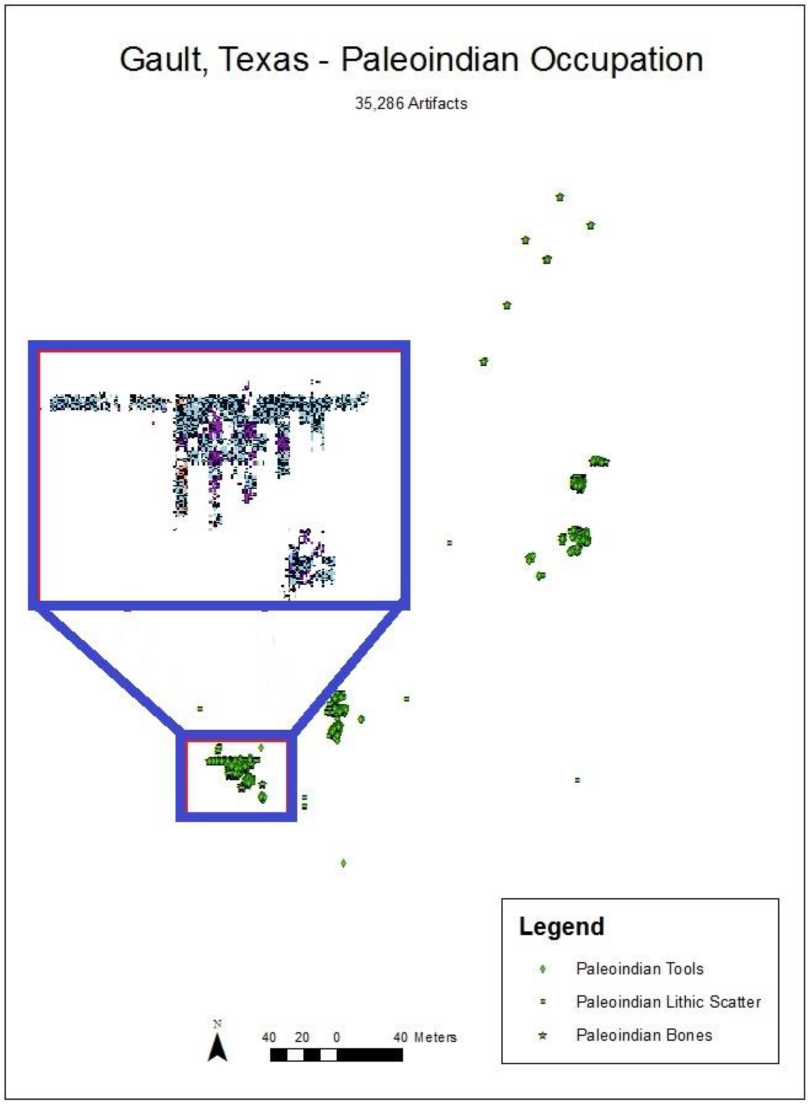

Figure 9 – Area Selection of Paleoindian Artifacts

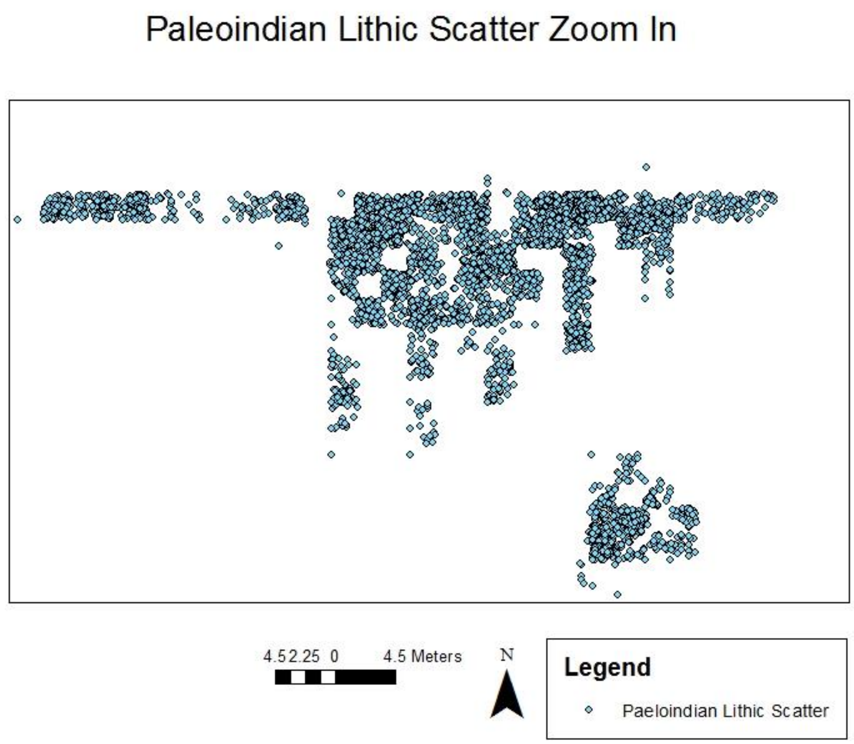

Figure 10 – Paleoindian Lithic Scatter Zoomed-in

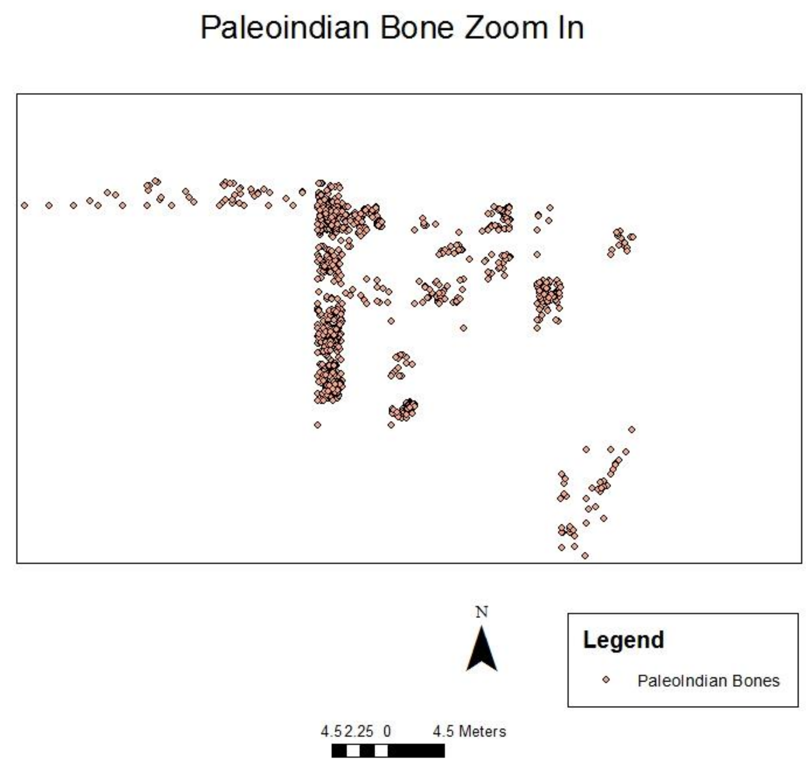

Figure 11 – Paleoindian Bones Zoomed-In

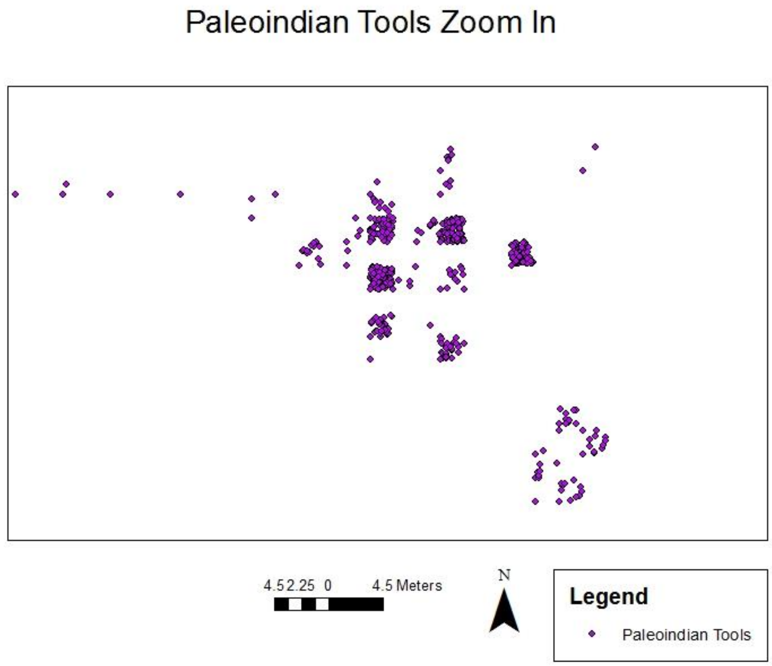

Figure 12 – Paleoindian Tools Zoomed-In

In order to truly understand if the high density of artifacts being found along the Western transect in figures 10-12, more excavation will be necessary. The area to the East of this transect has been excavated, but the area to the West of this transect does not have an excavation record. If excavation to the West continues to show that this high incidence of artifact density expands, there may be a greater anthropogenic pattern, such as a tool workshop that was utilizing the high density of lithic scatter that also leaves remnants of tool making. If, however, this transect remains the only area which has this density, and it is contained to the archaeological excavation units, then the anomaly in the data may be attributable to a modern difference in excavation or identification methods.

I began this project by collecting the various digitized records from nearly a century of excavation records at the Gault site. My goal was to provide a test case in which disparate data storage systems could be unified, using a software, GIS that would provide a platform for future inquiry and analysis. These data were provided by the Gault School of Archaeological Research, the organization that oversees all excavation and studies that take place in this site. The most time consuming step of this thesis, as well as the majority of GIS projects, was the coordination of data into a unified system that can be compared and analyzed. At the Gault Site, like at many others around the world, data from various smaller projects had been stored in a series of excel and text documents on the School's hard-drive, collected from the various paper copies of excavation field notes. I combined these data into a single attribute table that be uploaded into ArcGIS for analysis. To examine usefulness of this software in future inquiries, I created a series of eleven maps, which I used to examine the dataset as a whole, over time and by artifact typology. An analysis at two scales revealed the ability of GIS in identifying possible patterns, which can be used to create future excavation strategies.

Discussion

This thesis asks the question of how Geographic Information Systems can be applied to archaeological sites that have been excavated over many decades for the purpose of collecting various research project results and catalogued artifacts, while also standardizing future inquiry. The problem being that in sites which have been active for so long, there is typically a backlog of material which has yet to be catalogued, and artifacts which have been previously catalogued according to many different methodologies. Gault is a unique archaeological site, not only because it contains important information about the earliest people on this continent, but also because it is a site that has been excavated continuously for nearly a century. It is therefore not only an interesting question to examine how one can create a unified catalogue using the data digitized by many different sources, but then also find patterns in so much information. My results will allow for further research into human activity at the Gault Site and others, using a unified catalogue system.

Thus far I have provided histories of Geographic Information Systems and the Gault Site, as well as a methodological explanation into the case study of catalogue creation and how one might proceed in utilizing GIS to search for patterns in the spatial relationships of previously excavated artifacts. This thesis aims to answer the question of how effectively this particular technology can be applied to a body of data which is so disjointed. To that end, this thesis has successfully created a single catalogue system, which can be added to and built upon as more artifacts are identified, and will provide a platform for future analysis.

In figures 2-11, it is possible to see a visual representation of the artifacts uncovered during excavation at the Gault Site. Analysis of these figures shows that there is no definitive evidence of prehistoric activities causing patterning across the site as a whole, but there are areas of potential, where future excavation could reveal a greater anthropogenic pattern. At a site-wide scale there is a small variation in size and placement, by less than 1 meter, of the areas where the bones and tools have been excavated. This array could have many explanations. The most obvious being that, as previously mentioned, the Gault Site has been excavated by many groups of varying levels of professionalism, which could have resulted various excavation methodology, skewing the data. A second explanation being that this is the beginning of a pattern, where the distribution areas of bones and tools will continue to show expanding differentiation as excavation continues (Horton, 1984). It is estimated that only 3% of the site has been excavated (Texas Beyond History, 2001), therefore, any conclusion as to a definitive pattern would require significantly more archaeological excavation. A third aspect that would affect the way in which this data is interpreted would be the amount of available information in the catalogue. A complete picture of the soil as it was excavated or an understanding of the topographic area would allow for the comparison of possible patterns or clusters to the surrounding environment, to better understand cultural purposes behind an artifact location.

Figures 10-12 demonstrate the ability of Geographic Information Systems to be a useful tool in discerning patterns at a smaller scale and influencing future excavations. Figure 10 identified the excavation boundaries of the area. The large density of lithic scatter artifacts in this area provide a fairly complete image of what the excavation area looked like, including boundaries where excavation has and has not occurred. I used the excavation area defined by figure 10 to search for patterns among the lithic scatter and tools. I identified one linear transect in the western edge of this section, which is where a large percentage of the lithic scatter and tools for this area are located. Figure 10 shows the high density of lithic scatter that exists in this transect. In contrast, figure 12 shows a more patched density, where tools are focused in 3 rectilinear features, but after doing a statistical analysis what appears to be a low density area is actually the majority of the tools in this area. The shape and distance regularity of these areas indicate that these areas of high incidence are heavily affected by archaeological excavation. In order to understand how these densities of artifacts may relate to prehistoric anthropogenic patterns at the Gault Site, further excavation would need to take place to the West of this transect. Artifacts from excavation to the East of this transect are already apparent, without a continuation of this high-density. Should excavation to the West reveal a continued high density area, a collection of data on soil and topography can aid in explaining the continued pattern. If this high density of lithic scatter and tool remains contained to the excavation area of this transect, then it may be that this anomaly in the data has been caused by archaeological collection and cataloguing differences.

An important observation that can be drawn from the current catalog of artifacts is that without further excavation, it will be impossible to determine the full use of the Gault site. If, after further excavation, there is not an extension of the difference between tools and bones, then the conclusions about how the Gault site was used by its populations would be substantially altered if there were to be a distinction between the two artifact distribution areas (Wobst, 1976). In this case, it is important to note that any pattern of such small variation, identified at this stage of research, could lead to different conclusions once the entire site has been excavated.

I began this project with a collection of digitized data, which accounted for 2 million artifacts. I was only able to map 47,000 of these artifacts, because of those that lacked an identification or coordinate information. Without coordinate information, Geographic

Information Systems cannot be used, because all entered points are displayed using their location in space. This lack of coordinate information represents the largest limit to the use of GIS in analyzing data which has been collected using multiple methodologies and in varying levels of professional excavation. Without identification information, it is not possible to group artifacts by category or fully understand the way in which artifacts relate to one another.

For future excavation, Geographic Information Systems provides the ability to look at multiple scales of artifact location, which range from the entire site to a single area. Using a comparison of lithic scatter, bones, and tools, I was able to search for differences and similarities that might suggest a change in prehistoric activity. The categories I created, however, were based solely on the artifact identification that most closely matched among each of the digitized records. In further research, it would be beneficial to not only re-examine these categories, to create a more definitive separation between the artifacts, but also to look at smaller categories within these large three, such as burned bone, as opposed to all bone, or drills, as opposed to all tools. These finer and more distinctly defined categories would provide a more accurate future analysis, and may provide more intricate activity patterns.

An archaeological site can only be fully interpreted when the evidence being used is complete and thorough, meaning it is of the utmost importance to havve a catalogue that can be easily updated while also being actively used. Geographic Information Systems, not only provides the visual representation of these artifacts, but would also serve as a valuable information center for the cataloguing of all aspects of information uncovered about each artifact in order to create an attribute table. At sites like Gault, where there have been decades of excavation before the digital age, much of the data necessary for a complete analysis will need to be both unified and digitized. Therefore, many of the benefits of GIS software are reliant on the available data.

Conclusion

At the Gault Site I have utilized the information on 47,749 of the 2 million artifacts that have been found, from the over 50 excavations by more than 20 organizations and persons since 1929. These data were then used to create an attribute table that included all qualitative and quantitative data currently gathered on each individual artifact, as well as larger analyses as they are done on the site. When displayed in ArcGIS, this attribute table provided a visual representation in space of how the artifacts are related to one another.

Geographic information systems not only provides the ability to store a table of artifact locations or to display that data into a map for presentations, but serves as a centralized platform for the entire cataloguing and organizing process of archaeological excavation data. The dataset I have created for the Gault site has allowed for the coordinating of many methodological differences into a single and widely accessible format which can be easily updated and expanded as excavations continue. Furthermore, as research into individual artifacts continue, qualitative data, such as photographs and relevant articles can be added to clarify the information being stored. Future researchers and students alike can access an entire body of data, from which a nearly infinite number of questions can be answered.

I explored the way in which Geographic Information Systems (GIS) might be applied to the Gault Site, in order to search for settlement patterns on this land that was used continuously for 14,500 years. I organized the disjointed body of data, created by professional and amateur excavations that have taken place since 1929, into a single system ready for analysis. My chosen analyses showed the ability to begin looking for patterns in the distribution of bones, lithic scatter, or tools at the Gault site. Future archaeologists now have a framework from which to build their own inquiries.

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I plan to continue this work at a PhD level by continuing to analyze the Gault site, using the technology of GIS to analyze artifact spatial relations, and create a more complete picture of how this land was used. I will be able to utilize not only unified recording methods, but new technologies for better geological and environmental data collection, to recognize the activities at each site and even detect new patterns.

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