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Remote sensing at the Broussard Mounds site: a prehistoric multi-mound site located in the Lower Mississippi River Valley

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REMOTE SENSING AT THE BROUSSARD MOUNDS SITE: A PREHISTORIC MULTI-MOUND SITE LOCATED IN THE LOWER MISSISSIPPI RIVER VALLEY

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
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in

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by

Benjamin S. Goodwin
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ABSTRACT

In order to test the effectiveness of various types of remote sensing for applications in archaeology, remote sensing data in the form of color infrared aerial photography, Airborne Terrestrial Applications Sensor (ATLAS) imagery, 35mm (black and white) and (color) infrared photography, and ground penetrating radar (GPR) were used at the Broussard Mounds site. Additionally, light detection and ranging (LIDAR) digital elevation imagery was downloaded, processed, and interpreted. Anomalies identified through the use of remote sensing were relocated geospatially and archaeological testing procedures were used to verify the presence of subsurface archaeological remains and to document the prehistoric cultural components at the site. Materials recovered from prehistoric cultural features at Mound B were attributed to the Smithfield Phase of the early Marksville Period. The excavations near Mound A identified a remnant of a late nineteenth or early twentieth century brick structure.

The types of remote sensing used at the Broussard Mounds site were found to have mixed results for locating archaeological features. The color infrared aerial photography and ATLAS data were not efficient because of the effects of seasonal vegetation, but the ATLAS imagery showed promise for identifying historic structures using the short wave infrared and thermal bands of the sensor. 35mm photography required greater control in order to be more effective, but also showed potential for locating historic archaeological features. GPR data indicated numerous anomalies with possible associations with archaeological features. However, excavations only verified archaeological features at three of the locations. Several other GPR anomalies were tested, but could not be confirmed archaeologically.
CHAPTER 1:
REMOTE SENSING USED IN ARCHAEOLOGY

Archaeology is useful for gaining insight into the behaviors and daily routines of long forgotten cultures. However, the process of recovering the information necessary to understand how past cultures existed is oftentimes very destructive. In addition, traditional methods of testing and excavating are often based only on random possibilities of locating useful information. Typically, archaeological reconnaissance is conducted through surface collection or shovel testing using random, stratified, or systematic sampling techniques. The accuracy of the “prospecting” process could be greatly improved if an efficient means of remote subsurface detection were employed. If remote sensing techniques are used for subsurface detection, the most information-rich locations can be honed in on for efficient use of time with the least amount of disturbance, thus making the testing phase of archaeology much more productive.

Research Objective

The objective of the following research is to investigate alternative remote sensing methods for archaeologists to use as guidance while conducting field investigations. This research will use several different methods of remote sensing in order to test the effectiveness of each for locating significant subsurface archaeological features at a multi-mound site known as the Broussard Mounds (16AN1). The types of remote sensing to be tested will include: aerial photography, Airborne Terrestrial Applications Sensor (ATLAS) imagery, ground penetrating radar (GPR), and 35mm color infrared and 35mm black and white infrared photography. As an additional data source, light detection and ranging (LIDAR) digital elevation imagery was downloaded, processed, and interpreted.
The Broussard Mounds site (16AN1) is recorded as a multi-mound site containing three contemporaneous mounds. However, only one of the three mounds has ever undergone significant archaeological testing. Previous testing at one of the three mounds, Mound B, uncovered a buried midden deposit, as well as several other features that have been only partially excavated. Mound B has also been impacted dramatically by historic and modern development. Remote sensing in the areas of the known disturbances at this site should provide excellent signatures for the identification of other unidentified cultural features at Mound B and the other mounds. The secondary research objective, outside of testing the applicability of remote sensing, is to prove or disprove the contemporaneity of the three mounds, through an analysis of the artifact assemblages and other cultural remains from each.

**Introduction to Remote Sensing**

The use of remote sensing equipment in archaeology is not isolated to a few accounts of chance findings of archaeological remains in the jungles of third world countries after they were viewed for the first time from the air. In fact, many archaeological projects are focused on applying remotely sensed data in order to locate cultural information more efficiently than with the use of standard sampling and testing procedures. Several research projects, such as Lynott (1997), Clay (2001), Johnson and Haley (2002), and others, have been conducted in which the main emphasis was on the application of remote sensing to archaeological investigations. However, even though some projects in the southeastern United States are now beginning to embrace remote sensing, archaeology has been slow to adopt the use of remote sensing methods into the regime of more familiar field techniques on a whole.

Publications of archaeological projects where the research was driven, or even aided to a
good extent, by remote sensing in the Southeast are difficult to locate. According to Fredrick Limp (1993), one of the main reasons why remote sensing techniques have not been frequently used in Southeastern archaeology is because of the initial failures of remote sensing to produce satisfactory results; disappointment was particularly acute because at the early stage in the development of the field expectations exceeded the technical ability of the equipment.

Another explanation for the rarity of remote sensing in the Southeast might be the framework of academic institutions. Conducting projects using archaeological remote sensing requires the willingness of archaeologists to commit themselves to learning the technology and to incorporate remote sensing into a project design (Limp 1993). Today, many academic programs are still using curricula that were developed around theories and paradigms of the 1960s and 1970s (Fagan 1999). The technology used in remote sensing had not been developed at that time, and so remain outside of the curricula. In addition, at present, the overwhelming majority of fieldwork is now being done in CRM, or “cultural resource management.” Highly competitive, CRM work requires archaeologists to be broadly trained and capable of conducting efficient projects (Fagan 1999). Thus, one might conclude that a good portion of remote sensing in archaeology is conducted through CRM. This might well be the case, however, CRM project reports are not as easy to come by as published academic research papers. Often referred to as “the gray literature,” CRM reports are commonly distributed to a select few. Usually, two copies of a report are prepared for distribution; one copy goes to the entity funding the research, the other goes to the bureaucratic organization in charge of handling cultural resource affairs. Thus, the majority
of CRM projects that incorporate remote sensing into their investigations go unnoticed by the archaeological community at large.

Another factor that tends to reduce the number of projects incorporating the use of remote sensing in academia, and especially CRM archaeology, is the initial costs associated with the purchase of equipment, and the perception of low return on investment once remote sensing is used. However, recent work, such as that by Johnson and Haley (2002) and Clay (2001), involved an array of remote sensing techniques and were specifically designed to test the effectiveness of different techniques and to validate the economic feasibility for CRM archaeology should such techniques be employed.

Remote sensing is defined as the ability to collect information without being in direct contact with the object being sensed. It most commonly refers to the use of instruments that can detect variations in electromagnetic radiation emitted, reflected, or absorbed by objects. Also, remote sensing may refer to the detection of the reflection or absorption of sound waves or the detection of the strength and direction of such things as magnetic fields or gravitational fields. Evelyn Pruitt is credited with coining the phrase “remote sensing” in the 1950s while working with the United States Office of Naval Research (Campbell 1996:8; National Aeronautics and Space Administration, Earth Observatory [NASA, EO] 2001).

Remote sensing can be thought of as having at least two major components. One of the components deals with the use of instruments from afar, such as airplanes for aerial photography or satellites for digital imagery, to view relatively large land and water areas on the earth’s surface (Campbell 1996). The other component is referred to as geophysical remote sensing; this deals with remote sensing instruments that are based usually on or just above the surface of the earth. Geophysical remote sensing is usually focused on the
identification of relatively small features beneath the earth’s land or water surfaces (Conyers and Goodman 1997). Types of geophysical techniques include Ground Penetrating Radar (GPR), electro-conductivity and resistivity, magnetometry, and gradiometry.

Sonar, the use of sound waves propagated through water, is difficult to place within either of the two classifications of remote sensing techniques. Sonar systems are somewhat analogous to aerial remote sensing techniques, but the aircraft is replaced by a watercraft, and the earth’s atmosphere is replaced by water (Avery and Berlin 1992:17). However, sonar systems can also be similar to geophysical techniques in that they can be conducted without leaving the surface of the earth; the “atmosphere” studied, in this case the body of water, can be relatively small, and the features of interest can be fairly small as well.

**Aerial Photography**

The oldest form of what is generally considered to be remote sensing is aerial photography; aerial photography is also the most frequently used remote sensing technique. After a successful photographic chemical mixture was developed in the late 1830s by Louis Jacques Daguerre, Nicephore Niepce, and William Henry Fox Talbot, it was not long before photography took to the air.

**History of Aerial Photography**

Captive balloons were used for aerial photography as early as 1858 (Campbell 1996:5; Lillesand and Keifer 1994:50). Gaspard Felix Tournachon, also known as Nadar, is credited with the first use of an airborne camera system to obtain a remotely sensed image in 1859. This first remote sensing system was mounted on a balloon platform and was used to collect photos of a small village near Paris, France. The first aerial photograph to be obtained in the United States was collected over Boston in 1860 by James Wallace Black
using a captive balloon. A few years later this technology was utilized by General George McClellan to make photomaps of Confederate positions during the Civil War (Avery and Berlin 1992:21; Campbell 1996:5; Lillesand and Keifer 1994:50-51).

The first combination of photography and the airplane occurred only a few years after the invention of winged flight. In 1910, Wilbur Wright piloted the first plane to incorporate the use of aerial photography during flight. While flying over Centotelli, Italy, a reporter used a motion picture camera and Wright piloted the plane. However, it was not until World War I that aerial photography began to see technological improvement, in the form of film and camera advancements, and the demand for the use of aerial photography greatly increased. This trend continued through the Second World War until scientific applications for the use of aerial photography made notable advancements in research areas such as agriculture, mineral exploration, timber surveys, and zoology. One of the greatest technological advancements stemming from World War II was the widespread use of color infrared photography (Avery and Berlin 1992:21; Campbell 1996:5-6; Lillesand and Keifer 1994).

The first notable use of aerial photography for archaeological reconnaissance applications was in England, in 1922. O.G.S. Crawford used aerial reconnaissance to locate a number of Roman and Celtic archaeological sites. This work proved that aerial photography was a useful tool and established aerial reconnaissance techniques for archaeology in England (Avery and Lyons 1981:4).

Aerial photography was used to document and locate sites in many areas of the United States beginning as early as the 1920s. Among the first locations to be photographed was Cahokia, a massive Mississippian site in the American Bottoms near St. Louis, which
was mapped from the air in 1921. Other areas that were extensively researched using aerial
photography were Chaco Canyon in New Mexico, along with sites on bluffs near Blythe,
California, sites in southern Arizona, and other Native American habitation areas throughout
the southwestern United States. Over the last 80 years, aerial photography has been utilized
in many other areas throughout the United States (Avery and Lyons 1981:4).

The first site area to be documented using aerial photography in the southeastern
United States was the Poverty Point site near Epps, Louisiana. This mound complex was
extensively photographed to provide detailed maps of the concentric earthworks that are
present at the heart of the site (Avery and Lyons 1981:4). In fact, Ford and Webb (1956)
make extensive use of aerial photography when discussing the Poverty Point site. Their
published report is one of the first, if not the first, and one of only a few, archaeological
investigations from the Southeast to rely on aerial photography to such an extent. Numerous
references are made to the aerial photos included as three of the six plates in the publication.
Interestingly, one of the plates is a stereogram combination of two vertical aerial
photographs. One is an oblique aerial view, and one is a photomosaic of several flight lines
placed together to show an extensive area surrounding the Poverty Point site (Ford and Webb
1956).

Poverty Point is not the only archaeological site in the southeastern United States to
be photographed from the air in the early years of aerial photography. Actually, it was not
the only site in the Lower Mississippi Valley either. The Marksville site in Avoyelles Parish,
Louisiana, was photographed from the air several times, beginning as early as 1935 (Figure
1). Unfortunately, these photographs have never been sufficiently studied or documented.
Dache Reeves, a United States Army captain, personally collected several aerial photographs,
Figure 1: 1935 vertical (ca. 10,000 feet) aerial photograph of the Marksville Site (16AV1), taken by Dache M. Reeves, Captain U.S. Army Air Corp. James A. Ford Papers. Copy courtesy of Carl Kuttruff.
both vertical and oblique, over the Marksville Site in 1935. These photographs, one of which is presented in Figure 1, are unique in that they clearly indicate the presence of the outlying ‘lodge sites’ located in Gerard Fowke’s 1926 site map almost a decade earlier, as well as other potential cultural features (McGimsey 2003b:2; Ryan 1975). The negatives of these photographs were given to Frank Setzler and eventually deposited at the United States National Museum along with Setzler’s field notes and artifacts from his field excavations at the Marksville site (Ryan 1975).

Communications between Reeves and Setzler indicate that Reeves not only had a working knowledge of photography and archaeology, but also had established procedures tailored to looking for early cultural features at archaeological sites. Reeves describes in detail to Setzler how the photographs were taken and how they were studied after development (Reeves 1936).

**Types of Aerial Photography**

Aerial photography falls into two major divisions, oblique and vertical. These terms describe the angle, or point of view, used to acquire the photographs. Oblique aerial photographs were the first to be used. Oblique photographs are taken from the air with the camera aimed between the horizon and the ground. If the horizon is included in the picture, then the type of photo is referred to as a high oblique aerial photo. Low oblique photos do not have the horizon incorporated in the field of view. Figure 2 is an example of a low oblique aerial photograph that was taken of the Marksville site in 1935. Oblique aerial photographs are usually used to show particular features at low altitudes in areas with flat terrain (Avery and Berlin 1992:21; Avery and Lyons 1981:1-4; Campbell 1996:71-80; Caylor 1988).
The second major division in aerial photography is the vertical photograph. Vertical photographs have become the standard type of photograph used for scientific research. Vertical photographs are acquired by using a camera that is pointed at an angle directly below the platform that it is mounted on. This focusing point is referred to as the ‘nadir.’ Usually, vertical photos are acquired from airplanes flown in continuous lines of flight in which photographs are exposed with approximately 30 percent sidelap between parallel flight lines and 60 percent overlap between individual exposures along each flight line. Using overlap for each flight line allows features within the photographs that are recorded from two
different angles to be viewed in stereo using a stereoscope (Avery and Berlin 1992:21; Avery and Lyons 1981:1-4; Campbell 1996:71-80; Caylor 1988).

Vertical photographs can also be used to form what is referred to as a mosaic. Mosaics are composite images constructed from more than one vertical photo. Overlapping areas of vertical images are removed and the center areas of the vertical images are pieced together to form an image that shows a greater area of land coverage than was visible from each of the separate vertical photographs used for the mosaic. The mosaic that is constructed can be either a controlled mosaic, constructed using ground control points, or uncontrolled, where linear distances are unknown (Avery and Berlin 1992:21; Avery and Lyons 1981:1-4; Cambell 1996; 71-80; Caylor 1988).

The highest level of geometric correction and accuracy is used to create what is known as an orthophotograph. Orthophotographs are photographs that have been corrected for camera tilt and surface relief. When these photographs are pieced together the result is called an orthophotomosaic. The corrected images are further used as orthophotoquads when printed over topographic quadrangle maps (Avery and Lyons 1981:4; Campbell 1996:80-82).

**Types of Films and Filters**

There are numerous types of film used in aerial photographs, and several different types of filters for obtaining the desired exposure. The greatest division within photography, aerial photography not excluded, is the separation of film into the categories of Black and White or Color. These categories are then further divided into sub-categories of specific film type according to the portion of the electromagnetic spectrum being recorded. Black and White films contain emulsions that are comprised of various shades of gray when printed. The two most common types of black and white films are standard panchromatic and black
and white infrared, also referred to as panchromatic infrared. Panchromatic films record the portion of the electromagnetic spectrum that is usually visible to the human eye, although most aerial panchromatic films have a greater sensitivity in the red portion of the spectrum (Figure 3).

Figure 3: Graphical depiction of the electromagnetic spectrum (Lillesand and Kiefer 1994).

The portion of the spectrum that is visible to the unaided human eye is usually called the visible portion of the electromagnetic spectrum and is comprised of electromagnetic energy having wavelengths ranging from about 0.4 micrometers (blue) to approximately 0.7 micrometers (red). Black and white infrared film is similar to standard panchromatic film but has a broader spectral sensitivity. The spectral sensitivity of black and white infrared film is extended through the red portion of the spectrum and into what is referred to as the near infrared portion of the spectrum, approximately 0.7 micrometers to 0.9 micrometers (Avery and Berlin 1992:30-50; Campbell 1996:58-70; Lillesand and Keifer 1994:73-94).

In sum, all photographic emulsions record reflected light as it bounces off objects and is recorded on the negative material. As noted above, panchromatic film is used to record the reflected electromagnetic energy within the visible portion of the spectrum, while infrared
emulsions are used to record energy within the visible and a small amount of the near infrared portion of the electromagnetic spectrum that is reflected off objects within the view.

Panchromatic film is useful for resolving differential reflectance and visible colors for vegetation and land cover with low graininess, although the filters used for panchromatic film usually prevent the blue portion of the spectrum from being recorded on the emulsion. This filtering of the shorter (blue) wavelength energy removes what is called haze or fog. Selective scattering of electromagnetic energy in the blue portion of the spectrum causes haze on images. This scattering, also called Rayleigh scattering, is calculated as a function that is inversely proportionate to the fourth power of the wavelength. Once the haze has been removed through filtering, the image has greater tonal contrast and resolution.

However, using filters reduces the available light energy while the film is being exposed. In turn, this reduction of available light requires a longer exposure time; the darker the filter being used, the longer the exposure time required to achieve an adequate exposure (Avery and Berlin 1992:30-50; Campbell 1996:58-70; Lillesand and Keifer 1994:73-94).

Much like black and white films, color emulsions are also divided into at least two sub-categories. Conventional color film, or normal color film, and false color renditions, typically false color infrared, are the most common types used for color aerial photography. These types of photography can be produced as color-positive photographs or color-reversal transparencies (Avery and Berlin 1992:30-50; Campbell 1996:58-70; Lillesand and Keifer 1994:73-94).

When used for aerial photography, conventional color film is usually developed using a color-reversal film process capable of recording energy within the visible portion of the spectrum. Normal color film is comprised of three separate emulsion layers, as shown in
Figure 4; each is engineered through the use of dye couplers to be sensitive to blue, green, or red. Each layer is sensitive to only one of these additive primary colors. All three layers of a tri-emulsion color film are actually sensitive to Ultraviolet (UV) and Blue light as a natural property of the silver halides being used. However, the addition of a yellow filter between the top emulsion layer and the second layer prevents the transmittance of the shorter wavelength energy into the lower layers of the film, as shown in Figure 4. An added haze filter on the camera lens prevents unwanted UV energy, or wavelengths under 0.4 micrometers, from being recorded on the blue emulsion layer (Avery and Berlin 1992:30-50; Campbell 1996:58-70; Lillesand and Keifer 1994:73-94).

Figure 4: Graphical depiction of the layers used in color reversal film.
The development process for normal color film begins with the transformation of the silver halide material that has been exposed and converted to metallic silver. Subtractive primary color dye couplers, yellow, magenta, and cyan, are then added, replacing the blue, green, and red sensitive layers of the film. The next step in the process removes the yellow filter layer and all of the silver deposits, leaving only the subtractive primary colors. After washing and drying, the film is ready to be used as a positive image through which white light can be passed to create the additive primary colors in intensities similar to the original scene photographed (Avery and Berlin 1992:30-50; Campbell 1996:58-70; Lillesand and Keifer 1994:73-94).

Color infrared film, like normal color film, also has three emulsion layers, but these layers are different in that they are sensitive in the near infrared as well as blue, green, and red. In order to prevent total fogging or haze, a yellow filter must be used to block the UV and blue energy from exposing all of the emulsion layers (Figure 5). This filter can be applied to the film, as it is in normal color film, but it is usually added to the camera lens. Color infrared film is processed much the same way as normal color film. The only major difference is a shift in the natural colors, creating a false-color film. The normal representation of the additive primary colors, blue, green, and red, represent green, blue, and near infrared, respectively. Blue energy appears as black on the photograph because the yellow filter does not allow blue light to be transmitted onto the film surface (Avery and Berlin 1992:30-50; Campbell 1996:58-70; Lillesand and Keifer 1994:73-94).

**Key Points Regarding Aerial Photography**

Panchromatic photography is useful for making vegetation comparisons when an area is covered with a limited number of plant species. One example in which panchromatic
Figure 5: Graphical depiction of the layers used and color produced in color infrared film.

Photography is useful in studies of coniferous forests where the majority of trees are known to have similar reflectance values and variation in these values is easily detected.

As with the visible panchromatic emulsions, black and white infrared films offer good tonal contrast, resolution, and a wide exposure range, with low graininess. However, as with the filters used for removing at least some visible light from visible panchromatic emulsions, infrared photographs are recorded using filters to remove most of the visible portion of the spectrum and to enhance the resolution within the infrared portion of the spectrum. Infrared photographs can be useful for assessing vegetation differences within forests in which there is a large amount of variation in reflectance, such as hardwood or mixed forests.
Color infrared, originally developed for camouflage detection during World War II, is excellent for detecting vegetation differences. Living, and especially healthy, vegetation generally reflects much greater infrared energy than dead or diseased vegetation. The ability of color infrared film to detect differences in living vegetation and dead or artificial vegetation was used by the military to detect objects camouflaged in the visible spectrum. Needless to say, the ability of infrared film to detect relative health of vegetation is tremendously useful for many other applications. In 1956, Robert Colwell was the first civilian to apply the use of the near infrared to the study of plant sciences and he outlined the uses for aerial remote sensing techniques as they are used today (Campbell 1996:7).

The use of aerial photography to identify variation in the relative health of plants holds significant potential for archaeological research, especially at times when vegetation is under stress or in periods of rapid growth (Avery and Lyons 1981:11). Plant or crop marks can be used to identify archaeological features that are not visible from the ground surface. These marks are visible because of differential penetration of the root structures of plants, resulting from underlying soil differences, that can result in minute variations in color, density, or height in vegetation cover, and may indicate areas where archeological features are present. Climate and weather may also affect the visibility of such features. Dry weather produces tonal differences in vegetation, while wetter weather contributes to better identification through height and density. Vertical photographs are best for identifying plant and crops marks on the basis of density; oblique photographs, taken in midmorning or mid-afternoon, are better for height and tonal contrast, especially during dry summer months (Avery and Berlin 1992:231-4).
However, the archaeologist should not rely only on plant health as an indication of archaeological remains. Instead, aerial photo interpretations that use a number of different aspects, such as shadow marks, soil marks, and agricultural marks should be used (Avery and Berlin 1992:225-46). Shadow marks, as the name implies, are produced by obliquely aligned sun rays falling on topographic features. Objects that create variation in the terrain such as mounds and enclosures can often be identified through the use of shadow marks. Since shadow marks rely on an oblique sun angle, the time of day should be taken into account in order to collect photography when the sun angle is closer to the horizon; the greatest success for shadow mark identification is early morning or late afternoon (Avery and Berlin 1992:228-9; Miller 1979).

Soil marks are used to identify features that have dramatically impacted the natural soil profile. Color, texture, and moisture all play a role in the indication of archaeological features through the use of soil marks (Avery and Berlin 1992; Miller 1979). Soils with the greatest amount of variability between the surface and underlying subsoil typically yield the best results when using soil mark identification. Because of differential drying, the best time to collect photographs for soil mark identification is after plowing and heavy rainfall. Infrared photography tends to be more effective for identifying soil marks when soils are less variable; moisture variations are then more easily detected; if soil color variation is high, then standard panchromatic films are often just as effective as infrared (Avery and Berlin 1992:229-31).

No single type of photography can yield positive results all of the time; however, when several types of photography are used at various times and environmental conditions, a much wider range of information can be obtained. Each type of film has the potential to
illuminated different cultural features. All films work better under certain environmental conditions. In particular, seasonal moisture levels affect archeological feature detection. Generally, drier seasons are better for using aerial photography to conduct archaeological investigations; this is because of tonal differences created by variation in moisture retention (Avery and Lyons 1981:11). Attention should be given to the time of day that photography is collected in order to ensure that features of interest may be illuminated. In addition, the photographer must choose the appropriate color balance and the scale at which the photos are taken should be determined to maximize coverage and detail for the particular area of interest (Avery and Berlin 1992:238-9). Seasons of growth for specific vegetation should also be taken into account and special attention should be given to seasons when vegetation types are under stress or in periods of rapid growth (Avery and Lyons 1981:35; Miller 1979). Ultimately, the season for photography should be selected based on project objectives, because there is not a predefined period of the year that is best for all types of aerial photography in archaeological research (Avery and Lyons 1981:11).

35mm Infrared Photography

The basic principles for photographic film, including infrared, were discussed at the beginning of this chapter with regard to aerial photography. Most, if not all, of the same principles also apply to the use of 35mm infrared photography as well. Though mainly used in controlled environments to examine the relative health of plants, or as an artistically enriching form of photography for individuals inclined to be creative, infrared 35mm film, both black and white and color, have the potential to yield information to the archaeologist. As with aerial photography, vegetation is usually the main focus of infrared photography in archaeological studies in the Southeast. The leaf and blade mesophyllic structure of live
green vegetation absorbs an enormous amount of visible electromagnetic energy, but reflects most of the infrared. The greater reflectance of infrared energy causes the vegetation to appear light in tone while using black and white infrared film and red when color infrared film is used (Eastman Kodak Company [EKC] 1981). The ability of healthy plants to reflect a greater amount of infrared energy provides the researcher with a tremendous opportunity to investigate the relative health of vegetation at archaeological sites. The health of vegetation may indicate previously unidentified subsurface features because feature fills will have different soil moisture or chemical composition than the surrounding matrix, and these properties will affect plant health, either for better or worse; this effect can be enhanced by the seasonal or environmental stressors occurring at the time that photographs are taken.

The use of 35mm film has tremendous potential for locating subsurface features with only minimal ground reference control for the area being investigated, making 35mm film potentially valuable for locating medium to large features over a broad area with only minor time expenditure; this holds great potential for CRM investigations. Walker and De Vore (1995:131) also list some other 35mm format films that are useful for archaeological reconnaissance.

One of the reasons 35mm infrared film is useful is that it gives the archaeologist the flexibility to photograph any area or subject of interest in any number of potential views using a standard camera while in the field. The potential for research would seem to be tremendous within the scope of fieldwork and could be expanded even more if laboratory analysis was included. One of the potential applications for infrared photography is in the deciphering of illegible documents (EKC 1981). This technique might also hold value for gaining additional information about artifacts such as ceramics or lithics. For instance,
infrared photography might illuminate variations in the clays used for ceramics or particular
techniques employed during manufacture such as characteristics of the temper or coiling
methods used. Infrared photography might also be useful in highlighting flaking patterns on
stone tools. With the use of proper filters and special care to account for a few basic
differences between infrared and standard 35mm film, infrared photography can be used at
any archaeological site and in the laboratory and it can be used in any number of ways.

**Digital Imagery**

Digital imagery is another form of remote sensing; it is much like aerial photography
in the final display format. However, images derived from digital data are always created
from numbers and therefore, because they are digitally created, do not use natural lighting
conditions. Photographs may be considered images, but digital images should never be
called photographs.

In interpreting digital imagery, it is important to understand some of the basic
principles of electromagnetic energy, because digital imagery contains information from a
greater range of the electromagnetic spectrum than does basic photography or even infrared
photography. Various passive sensors that record digital images are capable of recording
from the Ultraviolet (UV) to thermal portions of the spectrum (10^{-1} \mu m to 10^{3} \mu m). Other
sensors focus on even longer wavelengths of energy. Synthetic Aperture Radar (SAR)
systems are active sensors that are designed to record digital images within portions of the
spectrum, from 10^{3} \mu m to 10^{6} \mu m, containing extremely long wavelengths of energy known
as microwave and/or radio energy (Henderson and Lewis 1998). Therefore, knowledge of
how energy is partitioned and how it behaves in the electromagnetic spectrum is crucial to
understanding how various types of digital imagery sensors are used.
Electromagnetic energy is comprised of two major components. The components are both sinusoidal waves; however, one is electric and the other magnetic. These parts of electromagnetic energy are aligned along perpendicular planes; thus the waves traveling within these two planes are at right angles to one another, both propagating in a parallel direction away from the source where the energy was generated. An idealized example of electromagnetic energy is shown in Figure 6.

![Figure 6: Graphical depiction of electromagnetic waves (Lillesand and Kiefer 1994).](image)

The basic equation for wavelength and frequency \( c = \nu \lambda \), where \( c \) represents the velocity of light, \( \nu \) represents the frequency of the wave, and \( \lambda \) represents the wavelength) is often used to classify electromagnetic energy within different areas of the spectrum. These classifications, which are part of a continuum of electromagnetic energy having no clear boundaries, are based on wavelength, and most often use the micrometer (\( \mu \)m) as the common unit of measurement. Using the aforementioned equation, one can see how wavelength and frequency can be thought of as being inversely related to one another. As
wavelength becomes greater, the frequency of the wave decreases. The amount of energy within the wave also decreases with an increase in wavelength, making energy generated from natural sources more difficult to detect as the wavelength increases.

As long as it is not at a temperature of absolute zero, all matter emits energy. Usually, the level at which most matter emits energy is far too low to be significant in terms of current remote sensing applications. The sun, however, is the most significant source of naturally occurring electromagnetic energy. As electromagnetic energy is propagated from a source and strikes a secondary earth body, the energy is subjected to three possible outcomes of interaction: reflection, absorption, or transmission, as shown in Figure 7. Generally, all three types of actions occur to some degree, with varying degrees of magnitude. Reflected electromagnetic energy is measured for the visible and near to mid-infrared portions of the spectrum using remote sensing devices; the same principle applies to photography and many other sensors. Absorption, although not typically used as a directly measured interaction, is the amount of energy not immediately reflected off of the object subjected to the energy. After absorption of electromagnetic energy occurs, it is transmitted, or re-emitted, as heat energy released by the body that absorbed the energy. This heat energy is emitted, in terms of terrestrial bodies in correlation with the earth’s ambient temperature, within the thermal infrared, also known as the far infrared, portion of the spectrum. This emitted heat energy cannot be viewed directly or detected using photography because energy within the thermal portion has wavelengths far beyond the detectable range of both human sight and currently used photographic film and camera lenses. However, using certain scanners and radiometers with a variety of detectors, this energy can be measured (Campbell 1996:29-46).
Some of the most basic principles of electromagnetic energy have been discussed here, but there are many other factors that play a significant role in the collection of remotely sensed data, such as atmospheric interaction, interactions with various earth features, and a host of other factors. For the sake of brevity, these are not discussed in detail here. The reader is referred to Avery and Berlin (1992), Campbell (1996), Henderson and Lewis (1998), and Lillesand and Kiefer (1994) for more detail.

Digital imagery is acquired using instruments that collect reflected or emitted energy from areas of the earth’s surface. The smallest indivisible portion of the image is referred to as a pixel, or ‘picture element.’ Each pixel, which is really a number value assigned to a corresponding brightness value, represents a small portion of an image; each image usually contains thousands of pixels. The term “resolution” is often used to describe the total “real
world” area, represented by an individual pixel. In other words, the resolution value referred to for digital images is determined by the total area of land displayed per pixel on the image. A one-meter resolution would mean that each pixel is equal to one meter on the ground.

The most common method of data storage for digital imagery data is in the form of binary code where the numeric values of zero and one are assigned in a series to elements known as bits. Each bit represents another numeric value calculated to the 2nd power. The product of each bit is summed, but the result is dependent on the position in which the exponential factor occurs within the binary data. Figure 8 depicts the general binary organization of a seven-bit data set. The arrangement of the binary data, along with the number of bits used, determines the digital number assigned to each individual pixel. One of the most commonly occurring bit arrangements is 8 bits, which allows for a digital number value ranging from 0 to 255 for individual brightness values. However, the data set does not have to be comprised of 8 bit data—the number can be higher or lower. The number of bits directly determines the range of variation within each pixel of digital data; the greater the number of bits, the greater the number of possibilities for variation, which varies exponentially (Campbell 1996:92-103; NASA, EO 2001:7-9).

The variations for each pixel value, or digital number as described above, taken as a single layer representing one type of sensed data, can hold a tremendous amount of information about an area on the earth’s surface. The resulting overall image of this single layer of multiple pixels, organized as an 8 bit data set with each pixel varying in shades of gray that are assigned a value from 0 (Pure Black) to 255 (Pure White), can be thought of as being similar to a panchromatic (black and white) photograph. However, if three layers of information are used simultaneously, one of the three primary colors is usually assigned to
each layer. When multiple layers are used, each layer is often referred to as a channel or band. The image created from the combination of multiple layers resembles a color photograph, but the colors may or may not be a representation of scenes that are visible with the naked eye. The addition of the two extra layers of information has the potential to greatly enhance variability among individual pixels within the image, thus increasing the chance for the human eye, or in some cases computer software, to locate important information not otherwise extracted from the image. The number of gray tones perceived by the human eye is on the order of 20 to 30; however, for color, the number of variations for different tints is at least 20,000 times greater (Campbell 1996:92-103; NASA, EO 2001:7-9). Needless to say, when dealing with digital data, it is often preferred to display information as layers of color, but this does not mean that the use of panchromatic images in not important. In fact, because of the nature of the single layer of information, panchromatic images can provide greater spatial resolution and/or sharpness than do composite color images.

There is a way, however, to take advantage of the qualities of both kinds of digital images. Increasingly, a method called “pan sharpening” is employed. When pan sharpening is performed, a computer software program is used to combine the color ranges, or spectral
resolution, with the greater spatial resolution of the panchromatic or single channel gray scale image. The resulting image is capable of maintaining both favorable aspects from the original images, the color range, and the sharper spatial resolution (Vrabel 1996).

Most digital data that is readily available is acquired from satellites placed in orbit above the Earth’s atmosphere. Thus, digital imagery emerged after the first rockets were invented. The first attempt at acquiring images from space occurred in 1946, when the United States and the Soviet Union both used German V-2 rockets, outfitted with cameras, to collect images as the rockets descended back to the surface of the earth. Although the V-2’s never obtained orbit, they were the first truly high altitude aircraft to collect imagery of the earth. When human space travel became possible in the 1960s, many photographs were taken from viewing areas of the spacecraft. Although these are examples of aerial photography rather than digital imagery, they represent the first attempts to acquire data from high altitudes and space orbit, thus leading to future developments in digital imagery aboard satellites (NASA, EO 2001).

The first satellites launched with the capability of making observations of the Earth’s surface were the Television and Infrared Observation Satellite (TIROS 1) in 1960 and the satellites launched as part of the first worldwide weather satellite system, the Environmental Science Services Administration (ESSA) I and II, in 1966. These satellites incorporated the first civilian use of advanced imagery systems capable of recording information into the infrared and microwave portions of the spectrum. Interest on the part of the National Aeronautics and Space Administration (NASA) and the United States National Academy of Sciences (NAS) to support research in remote sensing, especially applications in the fields of agriculture and forestry, increased in the second half of the 1960s and early 1970s. In
response to growing interests, the modern era of remote sensing was initiated in 1972 after the launch of the first Landsat satellite (NASA, EO 2001).

The Earth Resources Technology Satellite 1 (ERTS-1), later renamed Landsat 1, was the first civilian satellite to focus directly on making observations of the Earth’s surface. The sun-synchronous, earth-orbiting satellite was designed to collect data in several regions of the electromagnetic spectrum over large areas while maintaining an adequate level of spatial detail to allow for a broad range of applications. Landsat 1 carried two different types of sensors, the return beam vidicon (RBV) and the multispectral scanner subsystem (MSS). Ultimately becoming the primary sensor used, the MSS provided data for three bands in the visible portion of the spectrum, one in the near infrared, and one thermal band, with a spatial resolution of 80 m in each band except for the thermal. The combination of high spatial resolution, at least for the time, and multi-spectral capabilities led to practical applications in many fields. Landsat 1 was a tremendously successful endeavor (NASA, EO 2001).

Because of this success, six other Landsat missions followed, with the latest launched in 1999. Landsats 2 and 3 continued to use the same arrangement of sensors, with the RBV never used to the extent originally hoped because of problems associated with electrical components or other technical issues. Thus, later missions focused on the MSS as the primary sensor. Landsats 4 and 5 included an improved version of the MSS known as the thematic mapper (TM), as well as the MSS. Because the TM included a thermal band (as well as two additional infrared bands not included on the MSS), the thermal band of the MSS was discontinued. Spatial resolution capabilities for the TM were improved to 30 m in all bands except for the thermal, which went from 237 m for the MSS to 120 m for the TM. The MSS sensor was dropped entirely from the next two missions. Landsat 6 was equipped only
with the enhanced thematic mapper (ETM). This satellite was destroyed on launch. Landsat 7 was equipped with the ETM+, an even more advanced form of the thematic mapper. Landsat 7 is capable of recording data in a total of eight bands, three from the visible, three from the infrared, one from the thermal, and one panchromatic band capable of collecting information from a wide spectrum in the visible and near infrared. The spatial resolution was again enhanced, with the panchromatic band capable of collecting data at 15 m resolution and the thermal band improved to 60 m resolution. Landsat satellite data continues to be widely used and is recognizable as the most successful earth observing satellite program to date (Campbell 1996:161-80; National Aeronautics and Space Administration, Goddard Space Flight Center [NASA, GSFC] 1999).

Landsat imagery has not been extensively used for archaeological research in the Southeast. One reason for this is the relatively coarse resolution of the early systems when compared with the overall size of individual sites in the Southeast. However, a few projects conducted in the southern United States, such as those discussed in Limp (1993) and Custer (1986), have utilized Landsat data for large area land use and reconnaissance studies. The usefulness of the Landsat satellites for archaeological studies, particularly in the Southeast, will become much greater as spectral and spatial resolutions continue to increase (Limp 1993).

There have been other successful remote sensing satellites used for a wide variety of different applications. Because of the success of the Landsat program, the French space program initiated an earth observation satellite program in 1977, but did not launch a satellite until 1986. The French satellite system, which became known by the acronym SPOT, would also prove to be very successful, with a total of 5 satellites launched, the latest in 2002. The
SPOT satellites 1, 2, and 3 were equipped with dual sensors known as high resolution visible (HRV) instruments. The use of these two sensors allows for tremendous flexibility, including stereo imaging, multi-day coverage of a single area, and off-nadir viewing with an oblique alignment of either of the two sensors up to 27 degrees off vertical. The first three SPOT satellites recorded data in four bands, one panchromatic with 10 m resolution and three visible bands with 20 m resolution. SPOT 4 also used these sensors, but added an additional mid infrared band with 20 m resolution and a sensor called a VEGETATION 1 (VGT) instrument. The VGT was designed to study broad areas of vegetation cover. Because of its particular research focus, which does not require high spatial resolution, the VGT was only capable of 1000 m resolution. The SPOT 5 incorporated updated sensors called the high resolution geometrical (HRG) instrument which functions in an identical fashion as the SPOT 4 HRV’s, but with a greater spatial resolution of 5 m in the panchromatic and 10 m in the other bands. Also, the HRG included different stereo image geometry. The SPOT 5 uses a VGT instrument known as the VEGETATION 2 that is identical to the VGT on the SPOT 4 except for an improved locational accuracy (SPOT Image 2003). Like the Landsat satellites, the SPOT satellite systems have been very successful for earth observation. However, archeological studies in the United States have not readily made use of SPOT imagery, especially in the Southeast. Limp (1993) discusses two studies conducted in Arkansas that used SPOT data, both with mixed results, for archaeological site prediction. Once again, as the resolving capabilities of satellites systems become greater, SPOT systems included, so will their use in archaeological contexts (Limp 1993).
During the 1980s, development of significantly more advanced image collection systems began. Researchers at the Jet Propulsion Laboratory (JPL) ushered in a new form of remote sensing, known today as hyperspectral remote sensing, that is capable of collecting data in tremendous detail. Later development led to even more detailed systems known as ultraspectral remote sensing systems.

As this area of remote sensing continued to be developed throughout the 1980s and into the 1990s, another country joined the quest to develop advanced remote sensing satellite systems (Campbell 1996:401-8; NASA, EO 2001). The India Remote Sensing (IRS) program implemented the IRS-1A satellite system, with capabilities similar to Landsat and SPOT, in 1988, after operating two earlier remote sensing satellites in the 1970s and into the 1980s. The IRS-1A contained two arrangements of sensors, a single Linear Self Scanning (LSS-1) sensor, with limited spatial resolution of 72.5 m, and an additional pair of these sensors that functioned together. This last is referred to as LSS-2, and it had a spatial resolution of up to 36.25 m, twice as fine as the single sensor. The LSS sensors collected information within three bands in the visible and one in the near infrared portions of the spectrum. The IRS program was also very successful, leading to the launch of at least five additional satellite systems tailored to earth observation, with the latest being launched in 2000. The second satellite, the IRS-1B was identical to the IRS-1A. The IRS-1C, and later IRS-1D, satellites were equipped with an improved multispectral sensor known as the LISS-III that is capable of collecting four bands of data, two visible, one near infrared, and one mid infrared. The spatial resolution for the first three bands is 23.5 m and 70 m for the mid infrared. In addition to the multispectral LISS-III, both the IRS-1C and IRS-1D included a panchromatic camera with the capability to acquire stereo imagery at a spatial resolution of
5.8 m. The IRS-1C and IRS-1D also include another sensor for vegetation studies known as the Wide Field Sensor (WiFS) with a visible band and near infrared band at a spatial resolution of 188 m. Two other IRS satellites have also been launched with specific research foci of vegetation and oceanographic studies, as well as the collection of microwave data (Campbell 1996:185-6; National Remote Sensing Agency 2003).

Another country to launch a remote sensing satellite was Japan, which launched the JERS-1 in 1992 (Campbell 1996:234). Although the IRS, JERS, and other national satellite systems have not gained the popularity of the older Landsat and SPOT systems, they too have potential for applications in archaeology.

One of the more interesting trends to come about since the 1980s has been the transfer of satellite systems operations away from the public sector and into the private sector. In fact, even the development and deployment of the satellite systems has in some cases become an activity for corporations not agencies. Space Imaging is one such corporation. When launched by Space Imaging in 1999, IKONOS marked the dawn of the corporate satellite age (Space Imaging 2003). Since that time, other companies have also joined the remote sensing satellite industry. In 2001, Digital Globe launched the Quickbird satellite, which gathers information with a level of detail never before achieved (Digital Globe 2003).

**ATLAS Sensor**

In addition to the remote sensing satellite systems that are currently available, many high altitude sensors, mounted on aircraft, are becoming popular. One such sensor is the Airborne Terrestrial Applications Sensor (ATLAS). ATLAS data is collected using a NASA Lear Jet based out of Stennis Space Center in Mississippi. The ATLAS is a multi-spectral
instrument capable of recording information in 15 spectral bands (Figure 9). Six of these bands are located within the visible, with two of the six extending into the near infrared. Two other bands collect information from within the mid infrared portion of the spectrum, and six bands are devoted to the thermal portion of the spectrum. According to Don Powell, Research Scientist with Lockheed Martin Space Operations at Stennis Space Center, Band 9 does not collect data because of problems associated with cooling the sensor, thus there are only 14 bands available for data collection (Don Powell, personal communication 2003). The ATLAS sensor has a variable resolution capability and can collect data with a pixel size as small as two meters (Campanella et al. 1995; North Temperate Lakes Long Term Ecological Research 1999; Global Hydrology and Climate Center [GHCC] 1999). The use of up to 14 separate spectral bands offers an opportunity to identify small variations in vegetation and land cover that are only visible because of subtle differences within narrow spectral bands. Because of the number of spectral bands available and the relatively high spatial resolution, ATLAS seems a good candidate for locating buried archaeological features at relatively small sites. This data can also be easily acquired, if data has been previously collected for the geographic location in question, from NASA, at Stennis Space Center.

**LIDAR**

Another type of remotely sensed imagery used during this project was light detection and ranging (LIDAR) intensity data. LIDAR uses pulses of light ranging from ultraviolet to infrared that are transmitted from an aircraft toward the earth's surface (United States Geographic Survey 2002). The travel time of these pulses of light are measured as they reflect back to the sensor and elevations are calculated for reflecting surfaces; this enables topographic relief to be mapped after data processing. LIDAR altimetry provides data that is
Figure 9: Band limits for channels used on the ATLAS sensor (modified from GHCC 1999).
processed into detailed elevation models. Such data also has potential for extracting elevation models of the upper tree canopy and understory vegetation. With modern systems, each pulse of light can have five separate time measurements as it is reflected back to the aircraft; this allows for better penetration of vegetation than could be acquired using only a single time measurement. Most commercial LIDAR altimetry data sets are photogrammetrically corrected using airborne GPS during collection, and since LIDAR uses an active method of transmitted energy, it can be collected during the day or at night (Nayegandhi 2003; Spencer B. Gross, Inc. 2003).

**Ground Penetrating Radar**

As mentioned earlier, remote sensing data is not only collected from high above the surface. Geophysics is a sub-category of a broader field of remote sensing that is focused on the acquisition of data using several different types of instruments that are directly in contact with or placed just above the earth’s ground surface. Many of the instruments focus on the transfer and collection of electromagnetic energy (with the obvious exception of sonar equipment) and then attempt to quantify the behavior of the electromagnetic energy as it travels through the earth within a small area of interest. Some of the most common geophysical instruments used to detect buried archaeological features are resistivity and conductivity instruments, various types of magnetometers and gradiometers, and ground penetrating radar (GPR) systems (Bevan 1998:1-57; Conyers and Goodman 1997; English Heritage Society 1995; Heimmer and De Vore 1995; Lynott 1997; Milsom 1996). Of these, the most information with regard to detail, especially considering depth information, for underground features is generally collected through the use of GPR; however, the amount of information gathered can be overwhelming, thus making the process of identification of
particular features difficult when analyzing the data (Bevan 1998:43). One aspect of GPR
data that tends to make this process a little easier is the greater surface to depth control
offered over other forms of geophysical equipment. GPR detection focuses on interface
changes within subsurface strata, as opposed to other instruments that measure an electric
current or magnetic field that is directly correlated to volume, area, or mass of features;
therefore, GPR can often detect more deeply buried features and/or features of smaller size
than can other instruments (provided that the nature of the feature or soils associated with the
feature are sufficiently different from surrounding soils) (Bevan 1998:1-57; Conyers and
Goodman 1997; English Heritage Society 1995; Heimmer and De Vore 1995; Lynott 1997;
Milsom 1996).

GPR was originally developed as a tool for detecting subsurface voids, and had
applicability in numerous fields of study. Geologists extensively used GPR to locate various
subsurface anomalies; often features associated with tectonic interfaces. Soil stratigraphy,
bedrock depth, and groundwater research also made use of GPR technology (Davis and
Annan 1989). The different applications for GPR were very wide ranging, from testing the
electrical properties of earth, rock, and coal, to applications in subsurface testing under
highways and within coal mines for efficiency and safety (Pittman et al. 1984).

Archaeology was quick to follow, with some of the first applications occurring at
Chaco Canyon, New Mexico, in 1975. GPR began to gain popularity in the archaeological
community in the late 1970s and into the early 1980s when several other sites were surveyed,
both historic and prehistoric, and the GPR was shown to have success at locating several
types of buried archaeological features (Conyers and Goodman 1997:18-21; Vaughan 1986;
Wynn 1986). During the late 1980s and into the 1990s, archaeologists continued to use GPR
to locate buried anomalies. However, its use was still limited because there had been little
advancement in processing the data, other than velocity studies, in the almost two decades
since radar was first used in archaeology (Conyers and Goodman 1997:18-21).

In the southeastern United States, only a limited number of published projects have
made use of GPR technology. In the late 1970s, research began on St. Catherines Island to
investigate the mission site known as Santa Catalina de Guale. Part of the research at this
site called for the use of remote sensing to establish signature returns associated with
archaeological features for several different data types. One of the remote sensing techniques
chosen for the research at St. Catherines Island was GPR (Thomas 1987). Another major
publication from the Southeast that featured GPR was produced by Brain (1988). In an
attempt to use both magnetometry and GPR to locate archaeological features at the Trudeau
Site in Mississippi, Brain (1988) used the resources and personnel from Geophysical Survey
Systems, Incorporated (GSSI) to aid in the preliminary geophysical survey conducted at the
site. Even though the operators were not archaeologists, they were expected to produce
impressive results; when the results were not as rewarding as expected, Brain was quick to
consider the GPR reconnaissance a disappointment, but he did suggest that the technology
might eventually be developed to the point that it met expectations.

In the 1990s, Goodman began to study different aspects of GPR, using velocity
calculations to accurately measure depth and horizontal time slices with greater
enhancement. Additionally, simulation software was also developed to aid in the
identification of features (Conyers and Goodman 1997:21; Goodman 1994;). Through the
late 1990s and into the new millennium progress is slowly being made to further refine the
methods used to both collect and process GPR data. There is an increasing interest among
Southeastern archaeologists in using GPR as a tool for locating buried archaeological features. Recent examples of its use include projects from Arkansas, at a historic cemetery, and in Alabama, at the Moundville site (Gage and Jones 1999).

GPR uses electromagnetic frequencies of varying intensity, depending on the type of transmitting antenna used, that are sent as pulses of radio waves into some medium, usually the ground surface. Common GPR antennas use pulses that are centered around frequency lobes from 10 MHz through 1000 MHz and even higher, with the total signal ranging about two octaves around the center frequency (Figure 10). These pulses are then recorded, using a receiving antenna, as the radio waves that were sent by the transmitter reflect back toward the receiver. The radio waves are reflected to the receiver as a result of differential electrical properties within a heterogeneous medium (in this case, subsurface soils). Differences in the electrical properties at the interfaces of different soils are detected through changes in the reflected electromagnetic waves (Conyers and Goodman 1997:23-56; Rossiter et al. 1989a). The ability of the receiver to resolve various interfaces is related to the amplitude of the reflected waves. The greater the amplitude, the greater the visibility of the interface after the receiver detects the energy. Amplitude is affected by the amount of difference in the electrical properties of the medium, the greater the difference, the greater the amplitude of the reflected electromagnetic waves (Conyers and Goodman 1997:23-56).

Other factors, such as dispersion and attenuation, also have to be taken into consideration when dealing with the amount of energy being detected by a GPR antenna. As electromagnetic energy passes into the ground it becomes increasingly dispersed with depth. The detected reflections become weaker and weaker as the amount of total energy available
is propagated deeper into the ground. Eventually, no energy will be available for detection as all energy is completely attenuated at depth. The amount of time, or depth, that is required for attenuation is dependent on many variables related to the properties of the soils, water, or other media through which the energy is passed, and is also highly dependent on the center frequency of the transmitted pulse. Lower center frequencies travel further into the soil, while higher frequencies allow for greater resolution of subsurface features (Conyers and Goodman 1997:23-56).

GPR reflections are always recorded in two-way travel time; the amount of time required for the electromagnetic pulse to travel downward into the soil, strike a reflective subsurface material, and then return to the antenna to be recorded. Reflectivity off of materials and areas of varying electrical properties, dispersal, and attenuation can all take place during the return of the signal back to the antenna; thus, GPR signals should always be
thought of in terms of two-way time. Once the antenna receives the reflected signals, they are transmitted to a control unit to be digitally recorded (Conyers and Goodman 1997:23-56).

In order to associate GPR measurements with actual subsurface depths, the relative dielectric permittivity (RDP) of the medium that the signals pass through must be calculated. RDP is a measure of the ability of a material to allow the passage of electromagnetic energy. This number can be used to determine the velocity that the radar waves travel through different materials, and can ultimately allow for measurements of the depth to subsurface features. Usually, the higher the RDP, the slower the radar waves pass through. Table 1 shows general RDP values for several different types of material. The relationship of RDP and velocity can be seen in the equation $\sqrt{K} = \frac{C}{V}$, where $K$ is the RDP, $C$ is the speed of light (.2998 meters/ nanosecond), and $V$ is the velocity of the radio waves as they move through the soil. In fact, the difference in RDP between two materials is what changes the amplitude of the electromagnetic waves; the greater the change in RDP, the greater the amplitude, and the greater the magnitude of the reflection at the interface of the two materials (Conyers and Goodman 1997:23-56).

Table 1: Typical relative dielectric permittivity for selected materials (modified from Conyers and Goodman 1997)

<table>
<thead>
<tr>
<th>Material</th>
<th>RDP</th>
<th>Material</th>
<th>RDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>1</td>
<td>Dry Silt</td>
<td>3-30</td>
</tr>
<tr>
<td>Freshwater</td>
<td>80</td>
<td>Saturated Silt</td>
<td>10-40</td>
</tr>
<tr>
<td>Ice</td>
<td>3-4</td>
<td>Clay</td>
<td>5-40</td>
</tr>
<tr>
<td>Seawater</td>
<td>81-88</td>
<td>Permafrost</td>
<td>4-5</td>
</tr>
<tr>
<td>Dry Sand</td>
<td>3-5</td>
<td>Average Surface Soil</td>
<td>12</td>
</tr>
<tr>
<td>Saturated Sand</td>
<td>20-30</td>
<td>Dry, Sandy Coastal Land</td>
<td>10</td>
</tr>
<tr>
<td>Volcanic Ash/Pumice</td>
<td>4-7</td>
<td>Forested Land</td>
<td>12</td>
</tr>
<tr>
<td>Limestone</td>
<td>4-8</td>
<td>Rich Agricultural Land</td>
<td>15</td>
</tr>
<tr>
<td>Shale</td>
<td>5-15</td>
<td>Concrete</td>
<td>6</td>
</tr>
<tr>
<td>Granite</td>
<td>5-15</td>
<td>Asphalt</td>
<td>3-5</td>
</tr>
</tbody>
</table>
Changes in RDP also affect the shape of the radio signal as it passes through the ground as shown in Figure 11. GPR signals pass into the ground through a process known as ground coupling, which creates a spiked reflection often referred to as the near field zone. The shape of the signal as it is propagated into the ground is an elliptical cone with the long axis aligned parallel with the direction that the antenna is being moved. However, the RDP of the soil will determine how dispersed the cone of energy will be at any point during its propagation through the soil. Focusing of the radar cone can occur if the RDP is high, and dispersion can occur if the RDP is low (Figure 12). The amount of focusing and dispersion can change with any change in RDP at any point during propagation of the GPR signal within the ground and is caused by wave refraction within different material at varying depths (Goodman 1994; Conyers and Goodman 1997:23-56). Figure 13 shows a generalized GPR signal cone and illustrates how Snell’s Law can be used to determine the effects of RDP and the resulting footprint of the GPR cone with depth. The calculation in Figure 13 is for the footprint of the cone in the direction parallel to the antenna; this is the long axis of the cone. In order to calculate the perpendicular axis the result of the first equation must be divided by two.

Since RDP cannot be accurately measured for the entire subsurface in most circumstances, K is often an approximation based on tests within a certain matrix. Generally, one of the most efficient ways to test RDP is to bury an elongated metallic object horizontally within a straight wall of a hole at a known depth. A GPR antenna is then pulled near the hole, traveling over the top of the metallic object perpendicularly to the alignment of the object. The RDP is then calculated based on this depth and then used as a baseline.
Figure 11: Graphical depiction of variations in scattering and focusing for ground penetrating radar energy (Conyers and Goodman 1997).
Figure 12: Graphical depiction showing the propagation of radar energy in different mediums (Conyers and Goodman 1997).
Figure 13: Graphical depiction of a generalized GPR cone showing how Snell’s Law can be used to calculate the geometry of the cone with depth (modified from Conyers and Goodman 1997).

Two other factors that greatly affect GPR are magnetic permeability and electrical conductivity. GPR usually works better in cases where electrical conductivity is low. If soils have high iron content or contain calcium carbonate, then they may not be suitable for GPR reconnaissance, because these substances increase magnetic permeability and/or electrical conductivity. This is also the case with saltwater, as the salt greatly enhances the electrical conductivity of the water, causing the electromagnetic signal to disperse almost immediately after coming in contact with the saltwater. Varying salinities will have a linear effect on the attenuation of electrical conductivity, resulting in an increase in attenuation with increased salinity (Rossiter et al. 1989b). Indeed, moisture content in general can disrupt GPR returns. Ideally, GPR surveys should be conducted during a relatively dry period. Conyers (1999)

\[ A = \frac{\lambda}{4} + \frac{D}{\sqrt{K + 1}} \]

- \( A \) = approximate long dimension radius of footprint
- \( \lambda \) = center frequency, wavelength of radar energy
- \( D \) = depth from ground surface to reflection surface
- \( K \) = average relative dielectric permittivity (RDP) of material from ground surface to depth (D)
discusses how the addition of just a couple of inches of rain, at least in dry climates, can
cause pockets of water to yield high returns within different sediment layers. The water can
actually mask cultural features that yield lower reflection returns, though these features may
be clearly visible during drier weather.

Several factors must be taken into consideration when preparing to conduct a survey
using a GPR instrument. The first aspect to consider is how to establish suitable ground
control for relocating transects of GPR data. Ground control is usually achieved through the
use of a grid system (Conyers and Goodman 1997). Once ground control is in place, there
are several parameters that must be set in order to achieve the best possible results when
using a GPR unit; these parameters may vary somewhat depending on the type of unit being
used, but most are generally the same. One of the parameters already discussed is the
antenna frequency, which should be known before data acquisition begins. The time
window, recorded in nanoseconds, must be long enough to allow sufficient time for the radio
waves to travel into the ground and return to the receiving antenna, but short enough so that
attenuation of the signal is at a minimum. Time window adjustments can also be made in
order to look at specific segments, in vertical terms, within the area of data collection. The
shorter the time window range, the greater the resolution will be within the window because
of the stacking effect of the samples per scan. Samples per scan refers to the number of
digitally recorded samples used to describe the shape of the reflected radio wave as it is
recorded within the time window. The number of samples per scan usually ranges from 128
to 2048 in stepped increments that are twice the previous value. As the number of samples
per scan increase, so does the amount of resolution for each individual scan. The number of
scans per second can also be adjusted. Currently, GPR antennas can generate far more
information than can be recorded. Therefore, one method to more efficiently record data and to eliminate extraneous returns is to use a stacked method, where only a set number of scans are recorded per unit time, usually seconds.

Signal position, or the location where signals are being generated and first received, is also important. Signal position is usually considered as time zero. This location, however, can be adjusted with digital recording methods; a favored method is to lower time zero below the visible portion of the recorded radar profile or oscilloscope. Range gains can also be manipulated within the data, providing a boost to signals that are weakened through the attenuation that occurs with increased depth. Filtering of the data can also be implemented while collection is being completed to eliminate unwanted noise from the data. However, if filters are used, there is a possibility that important information could be removed from the data. One might be better off removing the noise after collection of the data has occurred, using post acquisition processing software (Conyers and Goodman 1997).

In addition to the parameters that can be adjusted in the field before and during data collection, there are several different post acquisition procedures that can be used. Filtering, as mentioned above, is one of these procedures. The frequency range of the data can be adjusted in any number of ways. Also, numerous other mathematical corrections and statistical methods can be employed to adjust GPR data. Background removal, surface normalization, deconvolution, migration, and any number of other algorithms to adjust the signals can be applied to the data to make corrections and tease out important information with regard to subsurface interfaces (Conyers and Goodman 1997; Inkster et al. 1989).

During post processing, the data are analyzed in one of two overall formats, vertical profiles or horizontal slices. The most frequently used format for GPR information has been
the single, vertical transect display (Bevan 1998; Conyers and Goodman 1997). However, archaeologists have found that the horizontal location of objects located with GPR was, in most cases, more important. For some time, archaeologists were required to painstakingly map out features visually from each individual transect of GPR data in order to effectively map large features encountered with the radar. Fortunately, software has been developed that is capable of mapping the data in horizontal slices, often referred to as time slices. The horizontally sliced displays still rely on the vertical profiles, but the vertical data are statistically manipulated to use and display a greater amount of information with less time expenditure than with maps created through manually locating anomalies (Conyers 2001).

Summary

In summary, remote sensing technologies cover a wide range of techniques that can be employed in archaeological research. Aerial photography, using either standard films or infrared, can be very valuable to the archaeologist for identifying features through the use of vegetation patterns, shadow marks, and/or soil marks. However, features that are potentially visible on imagery may not always be easy to identify, especially if spatial, temporal, and climatic conditions are not suitable. These same principles apply to 35mm infrared photography as well. Careful planning and interpretation are needed to ensure success.

Digital imagery can produce the same kind of evidence for archaeological features as that provided by infrared photography. However, the lower spatial resolution of most digital imagery makes the identification of relatively small archaeological features difficult. On the other hand, the broader spectral range offered by digital imagery greatly increases the usefulness of digital sensors in some applications, especially if the characteristics of the cultural features are only identifiable in portions of the electromagnetic spectrum beyond the
limits of photography. Finally, geophysical instruments such as GPR can be used to gather
information on smaller features than can be acquired using aerial techniques. The amount of
time required for collection and processing of GPR data in order to achieve coverage for
large areas of interest is great, but the level of information is equally as great.
CHAPTER 2:
THE BROUSSARD MOUNDS SITE

The Broussard Mounds site (16AN1) is recorded as a single component multi-mound site associated with the Gunboat Landing phase of the late Marksville period. This cultural component is confirmed, however, for only one of the three mounds at the site. A historic occupation at the site has been documented, beginning in the late eighteenth century and continuing until as recently as the 1980s. The area was once the location of Riverside Plantation, and several structures associated with the plantation are known to have existed at the site. A later occupation was present as well. In addition to the historic structures at the site, a small cemetery is located on top of one of the mounds. On the whole, very little is known about the relationship of the three mounds and the associated prehistoric components at each. There is also only minimal information available on the historic components at the site. This site was selected to test the efficacy of various remote sensing approaches because of the presence of prehistoric features that were identified during previous investigations but were only partially excavated.

Physical Setting

The Broussard Mounds site (16AN1), a prehistoric site comprised of three widely spaced earthen mounds, is located in northern Ascension Parish, near the town of Geismer, Louisiana, in sections 28 and 29, T9S, R2E (Figures 14 and 15). The site is situated near the confluence of Green Bayou and New River, just to the south of New River. The most prominent geological formation at the site is the extreme eastern edge of the natural levee of the Mississippi River, but portions of the site, or perhaps the entire site, is also located along the secondary natural levee of the New River (Figure 16).
Figure 14: Detail of a USGS 1:100,000 Baton Rouge and Ponchatoula topographic digital raster graphic showing the location of the Broussard Mounds site.
Figure 15: Portion of USGS Carville 7.5’ topographic quadrangle digital raster graphic showing the location of the Broussard Mounds site.
Figure 16: Geological map of Ascension and Iberville Parishes showing the classification of topographic features in the area of the Broussard Mounds site (modified from Howe et al. 1938). The location of the Broussard Mounds site is circled in red.

Prehistorically, during the St. Bernard Deltaic stage (3000 – 1000 B.P.), the New River served as a crevasse channel of the Mississippi River (Howe et al. 1938:64-9; Jeter et al. 1989:14; Saucier 1963:78, Saucier 1994). However, today, the New River system is independent of the flow of the Mississippi River. Thus, the New River system is unusual in character, due to the fact that its original, Mississippi crevasse levees are well concealed by the modern levees created by overflow of what is now this independent drainage. A short excerpt from Howe et al. (1938:65) exemplifies this:
“A distinct suggestion of dendritic drainage at the head of New River conceals the fact of its crevasse origin. There is nothing to indicate that two sets of natural levees run along the stream, a widely spaced, older set, of an important stream and a more closely spaced, more recent set built by the relict stream still existing in the old channel. The recent Quadrangles that now replace the old Donaldsonville are little better in this regard because they have no contours. If the New River territory were topographically mapped with 2-foot contours it would be one of the most instructive areas in the United States for the teaching of characteristics of streams in flat areas. A generation of Geologists might be trained with ideas far different from those of us who first viewed the Donaldsonville Quadrangle as the type example of a region in old age.”

To make interpretations regarding depositional events even more difficult, the variations in soil characteristics for the levees and deltaic surfaces are virtually unidentifiable as the stream crosses over the higher ground referred to as the “Oak Grove Island” (Howe et al. 1938). Oak Grove Island was once an area subjected to subsidence caused by deposition from a Mississippi Deltaic stage, most likely the Teche because of its associated dates, that was located further west than the St. Bernard and Plaquemine stages shown in Figure 17.

As the surface subsided, swampland formed in the areas that had dropped to elevations near sea level or below. Irregular networks of streams formed to allow for drainage of the swamp. Bayou Francois, located just south of the New River, was one of the main drainages for the Oak Grove Island area at the time that it was covered with swamp (Figure 18). Apparently, Bayou Francois was an earlier crevasse in this location, but was replaced by the New River; in the process, Bayou Francois yielded much of its flow to the New River. The Mississippi River deposits then shifted far enough east that the weight of alluvial deposits became focused east of Oak Grove Island. The shift eastward created enough force that Oak Grove Island was uplifted. In the vicinity of the Broussard Mounds site, however, the increase in elevation on Oak Grove Island is almost unnoticed. The location of the Broussard Mounds site is nearly at the apex of all of these phenomena, the
Figure 17: Sequence of Mississippi River deltaic lobes (modified from Saucier 1994).

early swamp deposits of Oak Grove Island that fed the Bayou Francois swamp drainage system that was subjected to later uplifting, the Mississippi River levee deposits, and the levee deposits from the New River. Many of the landscape features are visible in Figure 18. Ironically, referring back to Howe et al. (1938), this digital elevation model (DEM) was created with light detection and ranging (LIDAR) data using two foot contours.

Because of the various episodes of deposition of similar alluvial material, the differentiation of soils (or of depositional periods) is quite complicated and is based largely on relative elevation and dryness, not distinct soil differences (Howe et al. 1938). Needless to say, archaeological interpretations based on soil stratigraphy are also greatly hindered by the geomorphology and similarities of depositional soils.
Figure 18: Digital Elevation Model (DEM) created from LIDAR data, showing colorized 2-foot contours for the area of the Broussard Mounds site. Bayou Francois is located further east than the area shown in this image.
Historic Setting

The Broussard Mounds site was once part of Riverside (Mound) Plantation. In 1876, section 28 was unclaimed public land. Part of section 28 had been claimed by 1905 under the name of James Gleason. The rest of this area remained unclaimed. All of Section 28 later became known as the James Grayson Tract, which, in 1923, was purchased by Picard & Geismar Limited, a partnership between Benjamin Louis Geismar and Leon Picard. Ownership of the property was exchanged again when it was sold to Joseph Louis White (Jones et al. 1998). Section 28, including Mound C, remained in the White family until the late 1990s, when it was purchased by the present owners, Donald and Jill Smith (Jill Smith, personal communication 1999).

Etienne Coumo claimed section 29 shortly after the Louisiana Purchase, and the United States Congress confirmed ownership in 1807. The property became known as Mound Plantation, and was acquired by Schubal Tillotson and Romanta Tillotson in the early part of the nineteenth century. Mound Plantation encompassed all of section 29 and part of section 28. The plantation house was built on one of the mounds, presumably Mound A, and the Tillotson family cemetery was placed on Mound B. John Crossley and Sons acquired the plantation from the Tillotsons, and then sold the property in 1888 to Littleberry A. Ellis who renamed the plantation “Riverside Plantation.” The plantation was sold in 1897 to Irvin G. Randle, and in 1903, after Randle’s death, his widow sold the property to William R. Taylor. This deed mentions the presence of sugar processing machinery on the property. In 1905, Taylor sold Riverside Plantation to G. Adolphe Goudreau; as part of the deed, the plat map of Riverside Plantation was drawn up (Figure 19). By 1958, ownership of the plantation had been acquired by Edward Broussard, Jr. and Jewell Webb Broussard, who transferred
Figure 19: 1905 Plat Map of Riverside Plantation, including the area of the Broussard Mounds. The "Grave Yard" is on the summit of Mound B (Jones et al. 1998).
ownership to Edythe L. Greer and Nuby P. Greer in a land exchange at that time. In 1965, the property was sold to Jesse Richard Jones and John A. Jones. Ascension Industries Partnership purchased part of the plantation from the Jones family in 1981. This part of the plantation was again sold, in 1984, to V. Price Leblanc and his wife Shirley Wolf Leblanc. The Leblancs are the current owners of the portion of the site where Mound A is located. AJL Enterprises purchased another portion of the plantation from John A. Jones and his wife Mary Eubanks Jones in the early 1990s. Aubrey LaPlace is the president of AJL enterprises and is the current owner of the portion of the site where Mound B and the Tillotson family cemetery are located (Jones et al. 1998).

Previous Investigations

The Broussard Mounds site was first reported in 1972 by R.W. Neuman. Neuman took photographs and conducted surface collections in areas of the site. He noted the presence of three mounds. One (Mound A) had a modern house on its summit, and another mound contained a historic cemetery (Mound B). Near Mound B, Neuman reported prehistoric midden eroding into New River, and collected sherds from around the mound. Logistics prevented any investigation of Mound C (Jones et al. 1998). Figure 20 shows a general overview of the mound arrangement at the Broussard Mounds site.

Dennis Jones and Malcolm Shuman visited the site in 1987 as part of a mound-mapping project for the Museum of Geoscience at Louisiana State University, at which time they mapped each of the three mounds. At that time, they noted that one of the most striking characteristics of the site was the unusually wide distance between mounds. They (Jones and Shuman 1987:19) noted: “Although the mounds are currently classified as one site, they are so far apart that it would be difficult to define them as a mound group...if they are in fact a
Figure 20: Plan map of the Broussard Mounds site.

group, the plaza formed by the mounds would have been enormous: ca. 1200 x 1400 ft., …archaeological information on this site is so sparse that it would be impossible to say with any certainty that the mounds are coeval.” Mound A was reported as 76.2 m (250 ft) north - south, by 79.3 m (260 ft) east - west, and was approximately 2.7 m (9 ft) tall. Mound B was measured at 61 m (200 ft) north - south, by 51.8 m (170 ft) east - west, and was approximately 1.8 m (6 ft) in height. Finally, Mound C was determined to be 53.3 m (175 ft) north - south, by 42.7 m (140 ft) east - west, and was approximately 1.8 m (6 ft) in height (Jones and Shuman 1987).
As did Neuman, Jones and Shuman (1987) reported that Mound A, the largest of the three mounds, had a modern brick house on its summit. Jones and Shuman also suggest that Mound A may have been modified in order to facilitate construction of the house and its accompanying driveway. Mound B contained a historic cemetery on its summit, and was most likely modified during the construction of this cemetery. The graves were reported as being in a state of disrepair and the mound itself badly damaged by agriculture and/or the construction of a Gulf State Utilities high current electrical line located directly over the mound.

Both the mound and the graves were heavily overgrown with small trees and secondary vegetation. Despite the overgrowth and other disturbances, Jones and Shuman recorded the presence of four brick vaults and an inscription on one of the gravestones from the cemetery atop Mound B (Jones and Shuman 1987). The inscription read as follows:

“ELIZA
wife of Shubael Tillotson
Died Dec. 9, 1832
Aged 35 years
Also their son
Lafayette
Born Sept. 21, Died Nov. 21, 1832”

This same tombstone was observed atop Mound B during this thesis research.

Jones and Shuman reported that Mound C was the least impacted of all the mounds. The only notable feature was a depression in the eastern portion of the top of the mound that was approximately 20 ft in diameter and one foot deep. The area surrounding the mound was being used for cattle grazing, and was clear of underbrush (Jones and Shuman 1987).

During their investigations Jones and Shuman conducted surface collections around each of the three mounds; however, the only prehistoric artifacts recovered were a few small
non-diagnostic sherds from around Mound B. Jones and Shuman (1987) noted that the fields surrounding the mounds at 16AN1 contained historic ceramics, but the presence of a prehistoric midden near Mound B, reported by Neuman, could not be confirmed (Shuman et al. 1995).

Jones and Shuman returned to the site in 1995 during a cultural resources survey conducted by Surveys Unlimited Research Associates for R-S-H Engineering, Inc. Jones and Shuman were to determine the adverse effects of the placement of a liquid hydrogen pipeline 91 ft southwest of Mound B and 130 ft west of Mound C (Mound A was well outside the construction corridor). The most notable change in the landscape of the site since the two visited in 1987 was an enormous borrow pit that had been excavated from the area in the center of the three mounds. In 1987, this area had been a fallow field, but was now a crater that measured approximately 1500 square ft by about 12 ft deep. Also, the brick house that was atop Mound A had been razed, but the mound itself seemed to be impacted very little. Mounds B and C had suffered the least damage in the interim, the only noticeable differences being the further deterioration of the vaults atop Mound B (Shuman et al. 1995).

To determine the extent of cultural materials around Mounds B and C, Jones and Shuman (Shuman et al. 1995) placed auger tests at 10 m intervals in a line paralleling the pipeline right-of-way. Figure 21 shows the locations of these auger tests. The results of the auger tests indicated an extensive prehistoric midden deposit around Mound B. Another line of auger tests was placed roughly perpendicular to the right-of-way just to the south and east of Mound B at 20 m intervals. These tests suggested the presence of a midden 20 m south of Mound B. At Mound C, three auger tests placed at ten-meter intervals and extending 20 m
Figure 21: Plan map of the Broussard Mounds site showing 1995 pipeline right-of-way and auger testing of areas around Mounds B and C (Shuman et al. 1995).
west from the summit of Mound C indicated the presence of a potential prehistoric midden (Figure 22).

Figure 22: Plan map showing the location of auger tests at Mound C (Shuman et al. 1995).

During the 1995 investigations, further testing was conducted at Mound B; neither Mound A nor Mound C received any further archaeological investigations. Two 1 x 1 m test units were placed in the area southwest of Mound B where the most distinct and concentrated midden deposits were located (Figure 23). The excavation of these test units uncovered a stratum of midden extending approximately 20 cm to 40 cm below surface. A radiocarbon sample from Test Unit 1 yielded a one sigma calibration date of A.D. 1470 to 1655. Though
the sample was assayed to date the prehistoric midden, the result was not surprising given the historic artifacts recovered from this location (Shuman et al. 1995).

Several diagnostic sherds were recovered from the test units (Table 2 and 3). The sherds were attributable to a Marksville component (ca. A.D. 1-400), most likely late Marksville (A.D. 200-400) due to the presence of later variety ceramics. However, the researchers were surprised by the early ceramics, because they felt that the layout of the

Figure 23: Plan map of Mound B showing the locations of previous test units (modified from Shuman et al. 1995 and Jones et al. 1998).
mounds was typical of the Coles Creek Culture (A.D. 700-1200). In addition to the prehistoric artifacts, several historic artifacts were also recovered. These artifacts point to a late 18th or early 19th century occupation; this correlates well with the dates from the graves atop the mound.

Table 2: Material recovered by Shuman et al. (1995) from Test Unit 1.

<table>
<thead>
<tr>
<th>Material – TU 1 (1995)</th>
<th>0-10cm</th>
<th>10-20cm</th>
<th>20-30cm</th>
<th>30-40cm</th>
<th>40-50cm</th>
<th>Total</th>
</tr>
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</tr>
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<tr>
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<td>1</td>
</tr>
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<td>Bottle glass (clear):</td>
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<tr>
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<td>Total:</td>
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<td>25</td>
<td>19</td>
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Table 3: Material recovered by Shuman et al. (1995) from Test Unit 2.

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<td>26</td>
<td>58</td>
<td>53</td>
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</tbody>
</table>

* indicates 5 articulated sherds
Surveys Unlimited Research Associates returned to the site again in 1997 as part of a pipeline survey for Exxon Pipeline Co. This research focused on an area just to the north of Mound B and included a portion of the base of the mound. Auger tests were placed at 10 m intervals along two transects, both paralleling the right-of-way of another pipeline that was aligned roughly northwest to southeast, just to the northern edge of Mound B. Several of these auger tests revealed a stratum that was interpreted to be midden soil, a result consistent with the 1995 survey. Four 1 x 1 m test units were placed near the locations of the positive auger tests (Figure 23).

Test Unit 1 from the 1997 excavations revealed the presence of an extremely large tree that had been buried sometime in the recent past. This tree was a good indication of the amount of disturbance in the area. However, several prehistoric features were encountered in other units, including a buried house floor, with an associated two sigma calibration AMS radiocarbon date of A.D. 245 to 425, in Test Unit 3, and a feature interpreted as a trash pit in Test Unit 4, with an associated two sigma calibration AMS radiocarbon date of A.D. 350 to 605 (Table 4). Another feature from Test Unit 3 was interpreted as a premound postmold that was radiocarbon dated to a two sigma calibration of B.C. 1145 to 835. Relocation of the test units and the unexcavated portions of these features using remote sensing was a major goal of this project.

<table>
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<tr>
<th>Provenience</th>
<th>Laboratory No.</th>
<th>Material dated</th>
<th>Conventional radiocarbon age</th>
<th>Calibrated 1-sigma range (68%)</th>
<th>Calibrated 2-sigma range (95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Floor (TU3 - 1997)</td>
<td>Beta-110286</td>
<td>Charcoal</td>
<td>1710 ± 40 BP (13C=-25.1)</td>
<td>AD 320 – 405 AD 265 – 290</td>
<td>AD 245 – 425</td>
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<tr>
<td>Post Mold (TU3 - 1997)</td>
<td>Beta-110287</td>
<td>Charcoal</td>
<td>2840 ± 60 BP (13C=-26.8)</td>
<td>BC 1045 - 910</td>
<td>BC 1145 - 835</td>
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<tr>
<td>Trash Pit (TU4 - 1997)</td>
<td>Beta-110288</td>
<td>Charcoal</td>
<td>1600 ± 60 BP (13C=-31.5)</td>
<td>AD 410 - 550</td>
<td>AD 350 - 605</td>
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</tbody>
</table>
The artifacts recovered during the 1997 investigations are listed in Table 5 (Jones et al. 1998). Jones et al. (1998) concluded that, as indicated in the earlier investigation, the primary occupation of the Broussard Mounds site occurred during the Gunboat Landing phase of the Late Marksville period.

Table 5: Material recovered at the Broussard Mounds site from test units during 1997 investigations.

<table>
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<tr>
<th>General Provenience:</th>
<th>Test Unit 1</th>
<th>Test Unit 2</th>
<th>Test Unit 3</th>
<th>Test Unit 4</th>
<th>Total</th>
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<tr>
<td>Prehistoric Ceramics</td>
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<td>Baytown Plain</td>
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<td>243</td>
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</tr>
<tr>
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</tr>
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<td>4</td>
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One item of note in regard to Mound C is the state of preservation observed during research for this project. The earlier research conducted at the Broussard Mounds site by Shuman et al. (1995) and Jones et al. (1998) indicated that of the three mounds, Mound C was the best preserved. Unfortunately, this is no longer the case. The landowners at Mound C have borrowed nearly half of the mound to use for fill. This activity did provide an
opportunity to profile portions of the interior of the mound. However, this would require additional work to perform clean-up of the more vertically sloping sections. Time did not allow for profiling, nor were the landowners openly accepting of any work being done at the mound.
CHAPTER 3: MARKSVILLE CULTURE

Given that the principal occupation—at least the only occupation that left significant material culture—was of the Marksville culture, a thorough review of that culture is in order. Around 2100 years B.P. to 1600 years B.P., a manifestation of a unique sociocultural system emerged in the Lower Mississippi Valley (Table 6). This new culture, dubbed Marksville after the type-site (16AV1) in Avoyelles Parish, Louisiana, was closely related to the Hopewellian culture of the Illinois and Ohio River Valleys. The most striking similarities between the Marksville culture of the south and its northern Hopewellian counterpart are the presence of conical burial mounds and a suite of distinctive ceramic surface decorations (Toth 1988). As described in more detail below, conical mounds containing burials are quite similar for the time period between the two regions, but, as will be seen, interment practices appear to be very different, as does the internal construction of the mounds. In addition, ceramic assemblages from Hopewellian sites and Marksville sites are without a doubt very similar in form and are decorated with stylistic designs almost identical in nature, as shown in illustrations, Figure 24 and Figure 25, from Setzler (1933).

Marksville Chronology

The Marksville period can be divided chronologically, and also geographically (Jeter et al. 1989:127), into two recognizable cultural “units” (Greengo 1964:108). From about 100 B.C. until roughly A.D. 200, there is a significant occurrence of Hopewell-like ceramic motifs and conical burial mounds throughout the Lower Mississippi Valley (Jeter et al. 1989:127; Toth 1988:9). However, after about A.D. 200, Hopewellian influences become less pronounced. The ceramic motifs that signaled some unity between the two areas fade
Table 6: Cultural chronology of Louisiana (modified from Wells et al. 2001).

<table>
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<th>STAGE</th>
<th>PERIOD</th>
<th>CULTURE</th>
<th>TIME INTERVAL</th>
<th>PHASES</th>
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<td>VARIOUS TRIBES</td>
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Figure 24: Ceramic vessels from Marksville selected by Frank Seztler for comparison with Hopewell ceramic types (modified from Setzler 1933).

Figure 25: Illustration of Hopewell ceramic vessels from Mound City, Ohio; chosen by Setzler for comparison with vessels from Marksville (modified from Setzler 1933).
into a dissimilar array of designs with very similar design techniques that are closely related to, but different, from the earlier motifs. As an example of these trends, the continued use of zoned rocker stamping, although not dentate, continues through the late Marksville period, but the classic motifs, such as the use of the cross-hatched rim and raptorial and broad-billed bird designs, become less frequent (Greengo 1964; Phillips 1970:757-858). Also at this time, the scale of mound construction decreases; late Marksville sites tend to have fewer and smaller mounds, and a more dispersed population base is suggested (Williams and Brain 1983:362-3; Jeter et al. 1989:136). This later portion of the Marksville period is defined as the Issaquena phase in the Yazoo Basin by Greengo (1964) and is based primarily on ceramic attributes at the Thornton and Manny sites. Phillips (1970) elaborates on the concept of the Issaquena phase and further demonstrates the deviation in design from the early Marksville period. Jeter et al. (1989:127), perhaps to simplify discussion, attempt to raise Issaquena to cultural sub-period status; however, the term “Late Marksville” seems to be preferred, and will be used here.

In coastal regions of south Louisiana, early Marksville sites have generally been associated with the Labranche phase of the Marksville culture (Phillips 1970:898); the Smithfield phase has been defined for areas directly along the Mississippi River from Lake Verret to the mouth of the Red River (Toth 1988:196). The late Marksville (or Issaquena) phases recognized in the general area of the Broussard Mounds site are the Mandalay phase, for sites associated with the Teche-Mississippi River delta, and the Magnolia phase for sites related to the St. Bernard-Mississippi River delta (Phillips 1970:898-9). In addition, the Gunboat Landing phase has been defined for non-coastal areas along the Prairie Terrace near the Amite River and Bayou Manchac drainages (Jeter et al. 1989:136).
Previous Investigations of Selected Marksville Period Sites

Archaeological investigations of sites containing Marksville cultural components began early in the history of Lower Mississippi Valley archaeology. The earliest known controlled excavation of a Marksville period site was reported in 1904, after excavations were conducted in Coahoma County, Mississippi, by Charles Peabody and W.C. Farabee at the Dorr site (Toth 1988:13). Within a few years of the excavations at the Dorr site, C. B. Moore conducted a series of explorations at other Marksville period sites in Mississippi and Louisiana (Lamb 1983:12-13). Ironically, Moore abandoned an excavation at the site that was to become the Crooks site (16LA3) after testing was not satisfactory, and he completely missed the Marksville site, even though he was working nearby.

Gerard Fowke completed the first excavations at the Marksville site in 1926, under sponsorship of the Smithsonian Institution. Several other excavations at the Marksville site were to follow throughout the 1930s, with investigations by John R. Swanton, Winslow Walker, Frank M. Seztler, Gordon R. Willy, James A Ford, Robert S. Neitzel, and Edwin B. Doran (Lamb 1983:13; Toth 1988:14).

The Crooks site, mentioned above, became one of the most important Marksville sites ever excavated. The Crooks site report, published in 1940 by James Ford and Gordon R. Willey, details the excavations that were conducted by William T. Mulloy and Arden King. The report documents one of the most complete examples of early Marksville burial culture in the Lower Mississippi Valley (Ford and Willey 1940; Toth 1988:15).

Archaeological investigations conducted at the Crooks site were focused around the excavation of trenches through the center of the two mounds identified at the site. Excavations at Mound A, the larger of the two mounds, revealed the presence of 1,159
human burials interred in various positions that included extended, semi-flexed, flexed, partially disarticulated, bundle, and isolated skulls (Ford and Willey 1940:35-7). Three major construction episodes were identified for Mound A. First, a flat platform was prepared upon which a mass burial was placed. Next, the platform was capped by a conical mound construction, referred to in the report as the “primary mantle,” consisting of two distinct strata: bright yellow clay directly above the platform and basket loaded brown and gray clay over the yellow clay. The final stage of construction, referred to as the secondary mantle, overlay the earlier structures, and additional fill was also placed along the flank of the mound along one side. Burials were found throughout each of the different constructions, the greatest number being encountered on top of the original platform. Ford and Willey (1940) suggest that the burial practices at Mound A at the Crooks site are indicative of some type of charnel house activity; however no concrete evidence for such an activity was encountered.

Mound B excavations revealed the presence of 13 burials scattered throughout the fill, and the mound shape was interpreted to be a rectangular platform similar to the initial burial platform for Mound A (Ford and Willey 1940:30-2). However, the platform at Mound B was never used for a mass burial like the platform constructed for Mound A, and no additional fill was added over the platform. Ford and Willey (1940) conclude that the two mounds at the Crooks site were probably both constructed for use as mass repositories of the dead. Mound A had reached what was considered a point of completion in its use for interment, and Mound B was abandoned, for whatever reason, before a mass of human remains could be placed on the platform and then covered with a conical shaped cap (Ford and Willey 1940:31-2).
The Marksville site had many similarities with the Crooks site. Mound 4 at Marksville, although larger, contained the same type of overall construction as Mound A at Crooks. However, a burial vault covered with logs and cane was added to the platform of Mound 4 at Marksville (Ford and Willey 1940:32; Toth 1988:34). Mound 4 at Marksville also had considerably fewer burials than did Mound A at Crooks, with the total number of individuals ranging from 35 to 60. Approximately 75% of these burials were located within the vault or on the primary platform (Toth 1988:36). The variety in types of burials (e.g., extended, semi-flexed, flexed, partially disarticulated, bundle, and isolated skulls) found at Marksville was also seen at Crooks. In addition, the burials at Marksville, and to a lesser extent at Crooks, are often associated with wood or bark, and/or deposits of charcoal and ash (Toth 1988:34).

Fowke’s excavations at Mound 8 at Marksville indicate that it also contained the variation in burial types seen in Mound 4 and the two mounds at Crooks. However, Mound 8 was constructed without a burial platform; burials were placed in sub-mound pits that were covered by only a single episode of mound construction. Although the apparent differences in the two mounds at Marksville might in other contexts be thought of as being related to different periods of occupation, the ceramics from the mounds clearly indicate that these two mounds were constructed at almost the same time (Toth 1988:37). Thus, Mound 8 at Marksville may deviate from the general burial practices during the early Marksville period, or at least exemplifies greater variation on a whole for burial mound construction during the period. The range in variability for burial positions and in the preparation of burial areas (e.g. log tombs vs. burial platforms) at Marksville sites is also observed at Hopewell sites.
Variability, then, is a shared trait between Marksville and Hopewell cultures.

Toth (1988) reviews excavations by James Ford at Helena Crossing, and concludes that burial practices at that site were more similar to Hopewell practices to the north than those at Marksville and Crooks. Two mounds, Mounds B and C, were excavated at Helena Crossing. In Mound B, a large log tomb, containing the remains of two young adult males in an extended-supine position, was encountered. The tomb was covered by only a single episode of mound construction. Mound C contained five separate log tombs covered by a primary mound. Five groups of burials were laid on the surface of this mound, which was subsequently covered with the final phase of mound construction. All age groups were represented in the Mound C burials, and the most prominent burial position was extended (Jeter et al. 1989:132-3; Toth 1988:40). Twenty of the 26 burials encountered in Mound C were extended; there were three bundle burials and three isolated skulls (Toth 1988:40).

Both the log tomb in Mound B and the majority of extended burial arrangements at Mound C show greater similarity to Hopewellian sites further to the north than with Marksville sites further south, especially Crooks (Toth 1988:40). Many of the burials encountered at Helena Crossing contained exotic grave goods. Marine shell beads and cups, copper panpipes and earspools, pearl bracelets, and mica were among the items associated with burials at the site (Jeter et al. 1989:132-3; Toth 1989:52). Considered to be “status-related” artifacts, these exotic items are used as diagnostic markers for Hopewellian influence (Toth 1988:50-73). At Crooks, a wide range of status-related artifacts was encountered (Ford and Willey 1940:134-5). However, many of these were not directly associated with a particular individual. Even if all were considered associated, the number
of items per burial is significantly lower at Crooks than at Helena Crossing. However, the frequency of Hopewellian influenced artifacts is still high at the Crooks site. The Marksville site also contained items believed to be representative of Hopewellian status–related influence, but these are limited to platform pipes, a figurine, and one un-relocatable piece of copper that was considered to be a bracelet by Setzler and Ford (Toth 1988:50-73).

One item that occurs frequently within a very discreet period of time within Hopewell sites from 100 to 200 A.D. is the copper panpipe. Generally associated with higher-status burials, copper panpipes serve as possibly the best evidence of Hopewellian interaction. However, no copper panpipes have been recovered south of Helena Crossing. Carved stone platform pipes and figurines are also excellent markers of northern influence in the Lower Mississippi Valley, but in the Lower Mississippi Valley these items have almost exclusively been recovered as ceramic reproductions constructed of local materials. Several such ceramic platform pipes were recovered at Marksville and Crooks. Only one fragment of an exotic siltstone platform pipe was recovered at Crooks. One of the ceramic pipes from Crooks is an example of a crudely replicated Hopewellian-like effigy, and is the only known effigy platform pipe from the Marksville culture (Toth 1988:50-73).

Figurines associated with Marksville contexts are very few in number; a single example was recovered from both the Marksville and the Crooks sites. Each of these ceramic figurines was fragmentary and, when compared with Hopewellian examples, they were created with little regard for detail. The Crooks example was quite large in comparison with the fragment from Marksville and does not seem to match artistically with examples from Hopewell sites. Interestingly, no figurines or platform pipes were recovered from Helena Crossing (Toth 1988:50-73).
Most of the information on material culture from Marksville sites was obtained from excavations within burial mounds. There are significant differences in burials within the Marksville mounds in the Lower Mississippi Valley as compared to Hopewell mounds and those from Helena Crossing. These differences may represent a socio-political framework that is more egalitarian in nature for the Marksville culture, especially at Crooks (Jeter et al. 1989:137). The large number of burials and the variation in age and sex of individuals buried at Crooks suggests that the majority of the population may have been afforded a mound burial, unlike the Hopewelian practice of selected high-status mound burials (Toth 1988:33-4). Although some of the exotic items that appear within Hopewell sites do appear at southern Lower Mississippi Valley sites from the Marksville period, high status items are particularly rare when compared to sites from the Southeast overall (Toth 1988:50).

**Settlement and Subsistence**

Generally, Marksville sites are grouped into three major settlement categories: sites with conical burial mounds, village sites, and village sites with conical burial mounds (Jeter et al. 1989:136; Toth 1988:30-1). Though some projects have focused on obtaining additional information from Marksville village contexts in particular to recover subsistence and settlement information (e.g, Lamb 1983), on the whole, little is known about these aspects of Marksville culture (Neuman 1984:167). One of the most intriguing subsistence-related items is the report of maize and squash remains recovered within a ceramic vessel during Fowke’s 1926 excavations at Marksville. These cultigens cannot be relocated, and the possibility that the inhabitants of Marksville had access to these domesticates cannot be validated (Fritz and Kidder 1993:7). Williams and Brain (1983:401-3) suggest that the apparent adoption of Hopewellian cultural traits may have been fostered by the introduction
of maize into the southern Lower Mississippi Valley. However, even at Hopewell sites, the presence of maize agriculture has not been thoroughly documented. Research using direct radiocarbon dating of maize suspected of being associated with Hopewell components and isotopic analysis of human remains from the northern Lower Mississippi Valley does not support the idea of large-scale consumption of maize during the Marksville period (Jeter et al. 1989:137). Instead, a greater reliance on domesticated native starchy seed plants is suggested, in addition to the use of local fauna.

There is no direct evidence of horticulture at Marksville period sites in the Lower Mississippi Valley (McGimsey 2003a). Possible domesticated squash and gourd seeds were recovered from what were interpreted as Tchefuncte contexts in the multicomponent Morton Shell Mound, in coastal Louisiana (Jeter et al. 1989:140). If present during the Tchula period, the continued use of these items for subsistence into Marksville times is likely. However, the primary subsistence in coastal areas during the Marksville period seems to be based around the consumption of *Rangia cuneata*, a brackish water clam, and a mixture of locally available fauna, with little apparent change from the Tchefuncte period (Jeter et al. 1989:140-1; Lamb 1983:92).

Another poorly addressed aspect of research at Marksville sites is the construction of dwellings and other possible structures. Early excavations at the Marksville site identified four possible semi-subterranean structures; two that were rectangular in shape and two that were circular (McGimsey 2003b; Toth 1974:52-63). In an attempt to gain a better understanding of structures at the Marksville site, Ryan (1975) re-examined previous excavations of house structures and reportedly excavated a semi-subterranean circular structure in 1970. This circular structure was interpreted as being a non-residential structure
that may have served as a sweat lodge (Ryan 1975). No structures similar to the two rectangular and three circular ones identified at Marksville have been identified at other Marksville period sites.

McGimsey (2003b) discusses the 2000 re-excavation of one of the earlier identified circular structures at Marksville and re-excavation in 2002 of the circular structure excavated by Ryan in 1970. The general archaeological field interpretations from the 2000 and 2002 excavations did not deviate tremendously from those of previous researchers. McGimsey (2003b) and McGimsey et al. (2003) conclude that these circular features represent special purpose facilities of undetermined activity, tailored specifically toward a small portion of the community, as evidenced by the overall size of the features. However, evidence does not support the idea that these features were covered structures. According to McGimsey (2003b), posthole size is too small to have supported a roof similar to those identified from later structures. Further review by McGimsey (2003b) indicates that these features show some degree of commonality. A semi-subterranean central basin floor and a central fire pit link the design of at least two of the circular features with the two previously excavated rectangular structures; however, they differ dramatically in overall shape and wall post use (McGimsey 2003b).

Toth (1988:196-206) discusses his unsuccessful attempts to address four main issues at the Smithfield site (16WBR2) during his 1972 excavations. The site contained a Marksville village midden and a mound remnant. The four main issues addressed were: 1) to determine how much of the mound was still intact; 2) to obtain subsistence data; 3) to collect a radiocarbon sample; and 4) to obtain information on Marksville houses. The excavations at Smithfield did not accomplish any of the goals initially set forth; the level of
mound disturbance was not identified, significant subsistence information was not recovered, the single sample of charcoal that was tested did not contain sufficient material to provide a radiocarbon date, and no house structure was encountered.

**Ceramics**

One of the most distinctive aspects of Marksville culture is the unique ceramic assemblage of the period. Common ceramic design attributes include broad U-shaped incisions, dentate rocker stamping, crosshatched and vertically incised rims, raptorial and broad-billed bird designs, vertically bisected circles, undivided circles, and alternately roughened rings. Some of these motifs were illustrated above in Figure 23. Although a range of vessel shapes have been recovered from Marksville sites, tubby pots seem to combine the elements that are generally considered most diagnostic of the *Marksville* variety; the bird motif and the crosshatched rim (Toth 1974:174-5). These distinctive Marksville ceramics appear to be present within both burial and residential contexts, as shown by excavations at the Smithfield site, the Crooks site, and from excavations within both contexts at the Marksville site (Toth 1974; 1988:197-206).

**Summary**

In sum, around 100 B.C. influences from the Illinois River and/or the Ohio River Hopewell cultures appear at sites in Louisiana. Midwestern Hopewell cultural traits appear rapidly and tend to be most prominent at sites directly along the Mississippi River. Toth (1988:72-3) suggests that this influence was not simply the spread of cultural ideas, but rather a rapid, although sporadic and unorganized, contact among Hopewell peoples with local Tchefuncte cultures through a population movement southward along the Mississippi River. The result of this contact was the adoption of Hopewellian ideas, particularly
mortuary practices and ceramic designs, by the local Tchefuncte groups. The expression of these traits is identified as the Marksville culture—local groups that incorporated, but modified aspects of the Hopewell culture as needed. This direct contact lasted for less than 300 years; and late Marksville cultural aspects, particularly ceramic motifs and settlement patterns, show little Hopewell influence. From about A.D. 200 to A.D. 400, this gradual modification of Marksville cultural practices continued, until new influences from the east, particularly the panhandle and northern peninsular of Florida, produced the later Baytown Period.
CHAPTER 4: MATERIALS AND METHODS

The objective of this thesis research was to investigate the efficacy of various aerial and geophysical remote sensing techniques that archaeologists could use while conducting field investigations. The Broussard Mounds site was selected as a good location to conduct such a test because of the presence of previously tested archeological features that were still in situ. In addition, the assortment of modern and historic obstructions and disturbances would offer a range of verifiable signatures for conditions that are commonly encountered during many archaeological investigations.

One of the key elements to conducting this research was the availability of remote sensing resources. Fortunately, color infrared photography and ATLAS data were collected during a flight over the site on March 10, 1999. These images were taken during flight 1 of mission 9908 between 16:28:59 and 16:28:29 UTC. The ground speed of the plane at the time of data collection was 225 knots at an altitude of 4,350 feet above ground level (4,500 feet above mean sea level). The aerial photography and ATLAS imagery were acquired from John C. Stennis Space Center. In addition, the Space Center made available a GPR instrument and technical personnel for use at the site. Much of the processing associated with the large data sets of ATLAS imagery, photogrammetric scanning and manipulation, and slicing of GPR files was conducted at John C. Stennis Space Center as well.

**Color Infrared Aerial Photography**

At the time that the ATLAS imagery was collected over the Broussard Mounds site, color infrared aerial photography was also collected from a Zeiss camera with a six inch focal length, mounted on the same aircraft. These photographs, frames 8, 9, and 10 of line 4
from flight 1 were shot at a scale of 1:9000 on March 10, 1999, and covered the entire recorded site area. The aerial photographs were intensively reviewed as positive transparencies using a loupe and light table, and any potential archaeological feature noted. Color paper prints were also extensively studied using a stereoscope. The photograph with the best site coverage, frame 9, was also digitally scanned using a photogrammetric scanner at 1200 dpi. After scanning, the resolution of the digital image was 0.5 m. The image was then georeferenced with the Carville NE digital orthophoto quarter quadrangle (DOQQ) which was downloaded from Atlas: The Louisiana Statewide GIS, a website maintained and operated by the Louisiana State University Computer Aided Design and Geographic Information Systems (CADGIS) Research Laboratory. The georeferenced, scanned aerial photograph was then compared with earlier historic aerial photographs from March 1, 1941 and January 11, 1953 that were scanned using a conventional flatbed scanner at 600 dpi at the Louisiana State University Cartographic Library and later georeferenced along with the modern color infrared photograph. The georeferencing of these images was completed using the software package ERDAS Imagine. Once the imagery was georeferenced, any potential archaeological features were noted and transferred to vector layers for use in ArcGIS as a separate geographic information layer. This process was completed for the modern photograph, historic photographs, and the 1905 plat map for Riverside Plantation, so that most, if not all, twentieth century archaeologically related changes were noted.

ATLAS Imagery

The ATLAS imagery used for this project had been previously georectified and processed to a level that only required additional georeferencing with the DOQQ for the area. The georeferencing and image processing were completed using the software packages
ENVI, short for (the Environment for Visualizing Images), and ERDAS Imagine. Additionally, ArcGIS was also used to manipulate geographic information layers generated from the ATLAS data. The ATLAS imagery was collected as 8-bit data at a resolution of 2.5 m per pixel with 15 bands of spectral information, including channel 9, extending from approximately 0.4 microns to 12.5 microns within the electromagnetic spectrum, as previously shown in Figure 9. Processing of the ATLAS data involved the combination of multiple bands, contrast stretches, and various sampling adjustments to create images that were favorable for visually identifying potential archaeological features. Once potential features were identified the geographic location was noted and later re-located using ArcGIS for cross referencing with information from other forms of remote sensing used.

**Ground Penetrating Radar**

On August 25 and September 15, 1999, personnel from John C. Stennis Space Center visited the Broussard Mounds to offer expertise, assistance, and the use of the GPR unit owned by NASA. The control unit used to conduct these initial surveys, as well as two other, later surveys, was a Geophysical Survey Systems Incorporated (GSSI) SIR System 2; a GSSI 500MHz transmitter/receiver antenna was also used (Figure 26). The initial GPR surveys focused on a large area surrounding Mound B. This area was sectioned into a 120 m (north-south) by 50 m (east-west) grid comprised of 10 m grid squares, aligned 56 degrees west of north. This was tied in to the Mound B datum, located on the northwest corner of the nearest steel utility pole to the east of the mound (Figure 27). The grid was established using PVC stakes as node markers (every 10 m); nylon rope and fiberglass tapes were used to mark lines as transects were being completed for individual GPR survey line data collection. The GPR was set for 8-bit data collection with a vertical range of 1 m, 32 scans per second, and on
Figure 26: Geophysical Survey Systems Incorporated SIR System-2 and 500 MHz ground penetrating radar antenna.
auto gain. Selection of the proper range was completed after a RDP test was conducted to
determine the velocity of the signal through the soil using a machete that was driven
horizontally into the earth at a depth of 30 cm in a nearby ditch cut. A strong return was
identified as the GPR antenna was moved across the location of the machete. Based on the
time window and measurement to the return on the GPR display and the known depth of the
machete, an RDP of 8 was calculated and applied to the data, thus providing a known depth
for signal returns. Transects were collected in 1 m intervals for grid cells directly adjacent to the toe of Mound B. Two meter transect intervals were completed for all other areas outside of the initial 1 m transects mentioned above (Figure 27). Transect lines were completed in various directions and lengths to attempt to cover as much surface area as possible in the least amount of time. A field log was kept to organize these data once files were downloaded onto a computer. Data from Mound B required 94 separate radar transect files of varying lengths. This data was post-processed using the software package RADAN. The files were visually inspected and potential features were mapped with geographic coordinates, which were later transferred to ArcGIS for comparisons with other data.

Mound A and Mound C were also surveyed using the GPR. On October 26 and 27, 2000, personnel from John C. Stennis Space Center once again visited the Broussard Mounds site. An area totaling 70 m east-west and 50 m north-south was sectioned off using PVC and fiberglass tapes as guides for individual GPR transects (Figure 28). The entire area was surveyed at 2 m intervals. The GPR setup used the same format as the previous survey at Mound B, except for the vertical data range. This was accidentally set to one meter based on an RDP of 18 instead of 8. The incorrect range was adjusted during processing to reflect an RDP of 8, but the vertical depth was reduced to approximately 60 cm in the process. The data was set for 8-bit collection, with 32 scans per second, and the gains were set on auto gain mode.

The same procedure used at Mound A was used for Mound C, except the area around Mound C was reduced to only 30 m by 16 m northwest of Mound C (Figure 29). This area was surveyed with the GPR in transects at 2 m intervals. The data collected for these two mounds totaled 36 radar transect files for the area near Mound A and nine radar transect files
Figure 28: Plan map of Mound A at the Broussard Mounds site showing the location of the GPR survey area, test unit locations, and shovel test locations.
Figure 29: Plan map of Mound C at the Broussard Mounds site showing the location of the GPR survey area and shovel tests

for Mound B. The post-processing of these data was completed using the software packages RADAN, Fieldview, and GPR Process. Visual inspection of the processed vertical profiles and horizontal time slice data was completed and possible sub-surface features were noted for later location using geographic coordinates. The horizontal time slices processed for Mounds A and C were georeferenced using ERDAS Imagine. These data were also transferred into ArcGIS for comparisons with other data collected from the site.

35mm Infrared Photography

In addition to the other types of remote sensing that were used at the Broussard Mounds, an attempt was made to apply the use of 35mm color infrared and black and white
infrared photography to the investigations. The research goal focused on the ability to identify significant prehistoric or historic archeological features through vegetation differences using a standard 35mm point and click camera. In order to complete this process, 12 rolls of Kodak Ektachrome Professional Infrared EIR Film and 12 Rolls of Kodak High Speed Infrared Film (black and white) were purchased. The infrared film was stored below freezing in a home freezer. Twenty-four hours before each roll was to be used, the film was transferred to a refrigerator compartment. Three hours before use, each roll was transferred to room temperature conditions. This storage and acclimatization process was completed to insure longevity of the film and to avoid the possibility of damaging the film through condensation affects (Eastman Kodak Company 1996; 2000).

The camera used for infrared photography was a Pentax ZX-50. Loading and unloading of the camera could not be completed in total darkness because of logistical considerations. However, the camera was loaded under thick blankets to eliminate as much light as possible while film was being handled in the field. During the exposure of the black and white infrared film, a Tiffen No. 25 (red) filter was used to limit the amount of unwanted visible light from the pictures; for the color infrared, a Tiffen No. 12 (yellow) filter was used. The focus was adjusted to the infrared mark on the camera lens, so that the longer wavelength of the infrared range would not create an out of focus image.

Before photography began at the Broussard Mounds, six rolls of each type of film were tested at various locations under various lighting conditions in an attempt to achieve the optimum settings for aperture and shutter speed. A photo log was maintained, noting the time of day, orientation with the sun, relative cloud cover, relative focus, relative zoom, aperture settings, and shutter speed for each exposure. These initial tests were submitted for
processing to Rocky Mountain Film Laboratories. Once the photographs and slides were returned, each scene was visually inspected for clarity, contrast, and overall quality. A list was compiled for the quality of the photographs after the inspection. Using this inspection as a guide, the remaining rolls of film were exposed at the Broussard Mounds. A photo log was also kept for these photographs, recording the shutter speed, aperture, time of day, facing direction, relative location at site, film speed, and any other settings particular to the camera. The black and white infrared film was shot with a film speed set at ISO 50 and the color infrared photos were taken at ISO 200. For black and white infrared photography a good center range, as determined through the initial tests for the shutter speed, was 1/60 second with an aperture setting of F/16. The best color infrared settings were determined to be 1/125 second at F/11. All shots were then bracketed, one up, one down.

**Archaeological Investigations**

Archaeological investigations began on March 10, 2001. Prior to this date, several prehistoric ceramic sherds had been collected during surface collections at Mound B. Only a single prehistoric artifact, an undecorated ceramic sherd, had been recovered at Mound C at the time excavations began, and no prehistoric artifacts had been recovered from Mound A. No additional artifacts were found on the surface of Mound C; however, a single greenstone celt was recovered from the surface of Mound A by the end of the project. All of these artifacts were bagged with information on the general location from which they were recovered. Additional surface collections were conducted around the periphery of the site and along New River. The artifacts recovered during these surface collections were also bagged with general provenience location.
Field Methods

Archaeological investigations began with two 2 x 2 m test units at Mound B. The locations of these test units were based on the results of the visual inspection of the GPR vertical slices (see Chapter 6 for further description of these excavations). These test units were placed within the previously established grid, aligned 56 degrees west of north, constructed for use with the GPR survey, shown in Figure 25. Test Unit #1 was located at 69N 01E. Test Unit #2 was located at 67N 07E. The northwest corner was used as the unit datum in each unit. The units were excavated using 10 cm arbitrary levels within cultural strata, with special excavation and collection considerations given to identifiably unique stratigraphy. All material, except that bagged for special handling, was sifted through ¼ inch hardware cloth, and all materials recovered from this operation were bagged for later analysis. Both test units were excavated to 120 cm below unit datum.

An extremely wet spring caused problems with water in both units. When water table levels were above the floor of the test unit, a 20 cm thick vertical section was removed from within a 30 cm by 30 cm area in the southwest corner. A standard bilge pump powered by a 12-volt automobile battery was then used to drain the unit as much as possible, so that the remaining portions of the test unit could be removed to the level of the bilge pump hole. The process was repeated as needed until water levels subsided. Once 120 cm was reached in both test units, a 50 cm wide trench was excavated to two meters below unit datum along one wall for each test unit. The trench in Test Unit #1 was located along the grid-north wall, and the trench in Test Unit #2 was located along the grid-south wall. After all excavation was complete, a single 50 x 50 cm column sample was also removed from the wall of each test unit, extending from ground surface to 120 cm below unit datum. In 69N 01E, the column
was placed 30 cm west of the southeast corner along the grid-south wall. The column was located 30 cm west of the northeast corner along the grid-north wall in 65N 07E. These 50 cm$^2$ blocks were removed to facilitate collection of an adequate amount of soil for Oxidizable Carbon Ratio (OCR) tests to be run on various strata of interest. Profiles were drawn and photographed for each wall from both test units at Mound B.

In addition to the above methodology, an intense salvage operation was necessitated after tropical storm Allison turned the two test units at Mound B into large rounded pits. Although walls collapsed in large sections and provenience information could have been salvaged for some of the area, in the interest of time, the wall falls were screened without regard to stratigraphy other than a general wall fall classification.

When features were encountered, a sample of fill material was bagged for flotation. Also, when large amounts of charcoal or bone were encountered, extreme care was exercised to remove these items intact. All features were mapped using hand drawn plan views of the feature and were excavated so as to get the best possible profile view (when applicable). Photography was also used to record plan and profile views of features whenever possible. Material recovered from within features was bagged separately from the surrounding matrix.

Excavations at Mound A began on September 8, 2001, and included the removal of two 1 x 2 m test units. These test units were placed end to end to create a 1 x 4 m excavation area. This small trench was located 50 meters to 51 meters north and 22 meters to 26 meters east of the Mound A datum, which was spray painted on the concrete house foundation located on the summit of Mound A, shown in Figure 28.

The location of the test units was based primarily on the results of a visual interpretation of the processed GPR horizontal slices for Mound A (see Chapter 6 for further
description of these excavations). On the whole, methodology followed that for Mound B. Unit datum for both test units was located at 50 m North, 24 m East. Both test units were excavated to 80 cm below unit datum. Though a sump was used as described for Mound B, at this point, water levels became unmanageable.

In addition to the removal of the two test units at Mound A, a series of shovel tests were placed at 30 m intervals along the north, east, and west sides of Mound A, shown (Figure 28). A total of seven 30 cm$^2$ shovel tests were placed around Mound A, with five others placed at one meter intervals in a cruciform pattern centered around 80N, 15W. The shovel tests placed around the mound were done to gain additional information regarding the occupation and/or construction of Mound A. The shovel tests that were placed around 80N, 15W were excavated to locate an anomaly identified through visual inspection of GPR horizontal slices. All of these shovel tests were excavated to at least 60 cm below surface, with the deepest tests approaching one meter or more in depth. The profile from one wall of every shovel test was drawn.

Archaeological investigations at Mound C did not get underway until April 28, 2002, when a decision was made to test the anomalies located through a visual inspection of GPR horizontal slices. However, these anomalies were not investigated through the use of test pits, but rather through the use of shovel tests that were placed over locations where the anomalies were identified. Five 30 cm$^2$ shovel tests were placed at various locations to the northwest of Mound C (Figure 29). From the Mound C datum, the tests were located at (3N, 29.5W), (0N, 15W), (11N, 17W), (21N, 21W), and (30N, 20W). All shovel tests were excavated to one meter, except (11 N, 17 W), which was stopped short of a meter because of water. A one inch soil corer was used to extend the stratigraphic profiles of each shovel test.
to at least 120 cm below surface. A single wall was profiled and these profiles included strata encountered in the soil cores.

**Laboratory Methods**

All of the artifacts and samples recovered during the excavations and surface collections at the Broussard Mounds were transported to Johnston Hall, a temporary storage location for the Museum of Natural Science Archaeological Laboratory at Louisiana State University. Once at Johnston Hall, these materials were processed according to the guidelines set forth by the Louisiana Division of Archaeology. In addition to the artifacts recovered from this research, artifacts from all previously recorded investigations were acquired, or relocated in the case of the few artifacts curated with the Division of Archaeology. The cataloging information obtained from these materials was used in order to maintain consistency in the method used for all investigations at the Broussard Mounds site. However, it should be noted that the cataloging and curation process is ongoing at the time that this thesis is being prepared.

The artifacts were first washed using a water bath and soft toothbrush, then allowed to air dry. Material classes were then established for every provenience. Catalog numbers were assigned to each class within each provenience when only bulk material was present. The bulk material classes included: brick fragments, gravel, heavily rusted iron or steel fragments, small bone fragments, and etc. The bulk items were simply weighed and cataloged, with no individual count provided. All other items, e.g., pottery, ceramics, lithics, were weighed, counted, and cataloged according to class and provenience.

All historic ceramics were separated from the assemblage for further analysis to determine ware types and decoration. Dates of manufacture were determined using Hahn
and Castille (1988) and this information was used to determine the time period of deposition for historic features. Decorated prehistoric ceramics were separated and analyzed to determine type and variety according to the system discussed in Phillips (1970). Other diagnostic artifacts were analyzed, when applicable, to offer insight into the chronological history for occupation at the site, and any additional information regarding feature function.

Soil stratigraphy was assessed in the field, using the Munsell soil color chart and a basic textural description. However, as previously mentioned, the soils encountered at the Broussard Mounds site were difficult to distinguish; therefore, the accuracy of the field assessments were questioned. So, to more accurately identify the soils, a one-quart sample of soil was collected from each identified stratum. A particle size analysis was completed for each sample using a semi-quantitative method as follows: Munsell color was re-recorded; then, small clear plastic vials were filled to approximately 30% with soil from each sample; water was then added to fill the vials to approximately 80% capacity; the samples were shaken until all of the soil was suspended in solution; the vials were left undisturbed for 72 hours, at which time the constituents of the soil had settled into identifiable layers of varying particle size; the vertical thickness of each layer was then measured using a metric ruler and relative percentages were calculated; finally these percentages were used to derive the overall soil type for each stratum based on a standard soil texture triangle. The results of these tests are presented in Tables 7 and 8 (see Chapter 6 for further description of these soils).

Laboratory analysis also included the drying and sorting of material for radiocarbon and OCR samples. A total of 18 radiocarbon samples were collected, not including various smaller collections of bone and charcoal bagged with artifacts. In addition to the radiocarbon samples collected, 12 OCR samples were collected from two separate 50 x 50 cm column
Table 7: Table showing results of particle size analysis for soils recovered at the Broussard Mounds site.

<table>
<thead>
<tr>
<th>69N 01E</th>
<th>Munsell Color</th>
<th>Sand / Silt / Clay</th>
<th>Soil Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stratum 1</td>
<td>10YR4/2</td>
<td>86 / 10 / 5</td>
<td>Loamy Sand</td>
</tr>
<tr>
<td>Stratum 2</td>
<td>10YR4/3</td>
<td>60 / 23 / 17</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Stratum 3</td>
<td>10YR4/2</td>
<td>74 / 16 / 11</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Stratum 4</td>
<td>10YR4/3</td>
<td>46 / 37 / 20</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 5</td>
<td>10YR4/2</td>
<td>42 / 30 / 27</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 6</td>
<td>10YR4/2</td>
<td>32 / 42 / 21</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 7</td>
<td>10YR4/2</td>
<td>44 / 32 / 24</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 8</td>
<td>10YR4/2</td>
<td>41 / 39 / 20</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 9</td>
<td>10YR4/3</td>
<td>48 / 33 / 19</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 10</td>
<td>10YR4/3</td>
<td>45 / 32 / 23</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 11</td>
<td>10YR4/3</td>
<td>54 / 26 / 20</td>
<td>Sandy Clay Loam</td>
</tr>
<tr>
<td>Stratum 12</td>
<td>10YR4/3</td>
<td>21 / 74 / 5</td>
<td>Silt Loam</td>
</tr>
<tr>
<td>Feature 1</td>
<td>10YR3/1</td>
<td>25 / 25 / 50</td>
<td>Clay</td>
</tr>
<tr>
<td>Feature 2</td>
<td>10YR3/2</td>
<td>39 / 39 / 22</td>
<td>Loam</td>
</tr>
</tbody>
</table>

Table 8: Table showing results of particle size analysis for soils recovered at the Broussard Mounds site.

<table>
<thead>
<tr>
<th>65N 07E</th>
<th>Munsell Color</th>
<th>Sand / Silt / Clay</th>
<th>Soil Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stratum 1</td>
<td>10YR4/3</td>
<td>79 / 13 / 8</td>
<td>Loamy Sand</td>
</tr>
<tr>
<td>Stratum 2</td>
<td>10YR4/1</td>
<td>79 / 11 / 11</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Stratum 3</td>
<td>10YR4/2</td>
<td>50 / 36 / 11</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 4</td>
<td>10YR4/2</td>
<td>48 / 34 / 17</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 5</td>
<td>10YR4/2</td>
<td>36 / 43 / 21</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 6</td>
<td>10YR5/2</td>
<td>37 / 43 / 20</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 7</td>
<td>10YR4/2</td>
<td>36 / 48 / 16</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 8</td>
<td>10YR3/2</td>
<td>33 / 48 / 18</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 9</td>
<td>10YR4/2</td>
<td>44 / 40 / 16</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 10</td>
<td>10YR4/1</td>
<td>31 / 53 / 16</td>
<td>Silt Loam</td>
</tr>
<tr>
<td>Stratum 11</td>
<td>10YR4/2</td>
<td>39 / 43 / 18</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 12</td>
<td>10YR3/1</td>
<td>41 / 41 / 17</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 13</td>
<td>10YR4/2</td>
<td>43 / 43 / 14</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 14</td>
<td>10YR5/2</td>
<td>36 / 48 / 16</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 15</td>
<td>10YR4/1</td>
<td>34 / 50 / 16</td>
<td>Silt Loam</td>
</tr>
<tr>
<td>Stratum 16</td>
<td>10YR4/2</td>
<td>39 / 46 / 14</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 17</td>
<td>10YR4/2</td>
<td>44 / 37 / 19</td>
<td>Loam</td>
</tr>
<tr>
<td>Stratum 18</td>
<td>10YR5/2</td>
<td>36 / 43 / 21</td>
<td>Loam</td>
</tr>
</tbody>
</table>
samples that were excavated in one wall from each of the test units excavated at Mound B. Three of these OCR samples were collected from Feature 1 in Test Unit 69N 01E, three from Stratum 8 in Test Unit 65N 07E, three from Feature 2 in 69N 01E, and three from Stratum 12 in 65N 07E. Two of the radiocarbon samples were collected as bulk samples; one containing three gallons of material and the other, two gallons. The material for each of these two samples was removed from the bags in which they were collected and then spread on newspaper to air dry at the Archaeological Laboratory of the Museum of Natural Science at Louisiana State University. However, due to difficulties with separating the carbonized material from the soil matrix after drying, the radiocarbon samples were placed in a water bath to separate the datable material from the soil in the sample. After the samples were soaked, the material was continually stirred by hand within the bath until nearly all of the soil was suspended. At this point the samples were fine screened through window screen, and the carbonized organics collected. This material was then separated by hand using tweezers and magnifying instruments.

During excavations at Mound B, 16 bulk flotation samples were collected from Feature 1 (69N 01E) and Stratum 8 (65N 07E), and 17 bulk flotation samples were collected from Feature 2 (69N 01E) and Stratum 12 (65N 07E). These samples were processed at Johnston Hall using an agitation flotation tank. Three fractions were recovered for each sample; these included: fine screen material that floated from the flotation tank and was collected using a fine mesh nylon bag; coarser material collected from the 1/8 inch vinyl mesh cloth located within the flotation apparatus; and 1/16 inch fraction from the screen at the base of the flotation tank. Once these samples were collected, the heavy fractions from the mesh within the flotation apparatus were separated using tweezers and magnifying
equipment. Material from one of the radiocarbon samples and from the light fraction portion of one of the flotation samples was sent to Marie S. Standifer, Archaeobotanist at LSU, for further analysis. Any samples with sufficient charred material were separated as potential radiocarbon material. Four of the six radiocarbon samples dated for this project were recovered during flotation.

Summary

Four types of remote sensing were used at the Broussard Mounds site. The types of remote sensing used included both aerial and geophysical. Color infrared aerial photography, on-site infrared photography, ATLAS imagery, and GPR were the types of remote sensing tested at the site. The aerial photographs and the ATLAS imagery data were analyzed using computer software to aid in the relocation and ground checking of anomalies that were identified. Thirty-five mm color infrared and black and white infrared photography were used at the site after several tests were performed to optimize the quality of the photography. This photography was analyzed for any subsurface archaeological features expressed as anomalies in vegetation or soil patterns within the infrared portion of the electromagnetic spectrum. An area around each of the three mounds at the site was surveyed using GPR. The GPR data collected from the site was processed using computer software, and as with the aerial photographs and ATLAS imagery, these areas were relocated for testing using archaeological methods.

Archaeological methods used at the Broussard Mounds site included the use of two test units each at Mounds A and B, and shovel testing at Mounds A and C. The archaeological investigations were conducted in a manner consistent with most archaeological research, with the exception that the main focus was identifying anomalies
located through the use of the remote sensing methods mentioned above. Laboratory analysis was also conducted as most archaeological analysis and curation prescribe. The major goal of the laboratory analysis was to determine the chronology for the occupations and features encountered at the site. Only historic ceramic sherds and prehistoric decorated ceramic sherds were analyzed.

In order to corroborate dates at the Broussard Mounds site with the artifact assemblage, six radiocarbon samples were assayed, and twelve OCR samples were analyzed. Unfortunately, due to problems associated with the unusual nature of the soils at the Broussard Mounds site, initial tests of the OCR material cannot be accurately dated without additional soil cores from all observed strata at Mound B. Once collected and properly dried for analysis, the testing of future OCR cores will allow for a date to be derived from the earlier sample material. In addition to other special samples collected, 33 gallons of bulk flotation sample material were collected from Features 1 (69N 01E), Stratum 8 (65N 07E), Feature 2 (69N 01E), and Stratum 12 (65N 07E) during excavations at Mound B. These samples were processed using a standard flotation apparatus, and the fractions of heavier material were separated after recovery from the flotation process.
This project focused on the use of color infrared aerial photography, on-site 35mm black and white infrared and color infrared photography, ATLAS imagery, and GPR for locating archaeological features at the Broussard Mounds site. Results of the application of each type of remote sensing are presented below, along with a discussion. Although possible anomalies were noted for each data set, archaeological verification was only completed for the anomalies located with the use of GPR.

**Aerial Photography**

On March 10, 1999, 9 x 9 inch color infrared photography was collected over the Broussard Mounds site with a Zeiss camera at a scale of 1:9000. The photographs that were collected were done so from a single flight line with sufficient overlap to provide stereoscopic viewing for the entire extent of the site. After an extensive visual inspection of both positive transparencies and stereo pairs, using a mirror stereoscope, it was concluded that the aerial photographs were not as valuable as was hoped for the identification of unrecorded subsurface features (Figure 30).

One factor that seemed to play a significant role in the inability to identify archaeological features was the recent cutting of vegetation surrounding much of Mound A and outside of the tree-covered area near Mound C. Parallel lines related to tractor or combine rows are clearly visible when viewing the photographs using magnification. These rows mask any possible vegetation patterns associated with older subsurface features. Certainly, a more appropriate date could have been chosen for the collection of aerial photography, had the focus of the collection been archaeological in nature. Optimally, the
Figure 30: Portion of a Zeiss color infrared photograph showing the Broussard Mounds site. Photo taken at approximately 16:00 UTC on March 10, 1999.
date of collection should be scheduled for a selected green-up period for particular vegetation or during periods when plants are under stress, such as in early winter or late summer. Even though the date of collection for these photographs was not optimal for archaeological studies, some unusual patterns are visible in areas near Mound A and Mound C, particularly in the form of soil marks (Figures 31 and 32).

North of Mound A, faint patterns in the vegetative cover, represented by both dark and light coloration, are visible as pairs of parallel lines. These lines represent either historic road scars or modern field roads that provide access for hunters, borrow pit work, or some other activity. Several areas of soil discoloration are visible within the fields surrounding Mound A. In an effort to correlate vegetation and soil patterns that are visible on the modern imagery with historic structures and roads, two aerial photographs from 1941 and 1953 were georeferenced and visually compared with the recently acquired images. Several structures and roads are visible on the historic photographs in areas adjacent to Mound A. The swipe feature in ERDAS Imagine was used to inspect both modern and historic images for features that might coincide. This effort was inconclusive. Because of the scale of the historic images, a clear determination could not be made as to exactly where historic roadways were located. In order to clarify the problem of road locations and to more accurately quantify the location of historic structures, vector layers were created using ArcGIS, outlining interpreted locations for historic features from the early aerial photos (Figures 33-36). The vector layers were placed on the modern image for comparison, but still, no conclusive similarity in patterns was found outside of modern roads and obvious surface features. Only structures that could be confidently identified were in the established vector layers. A total of five structures were outlined from the 1953 aerial photo and four were outlined from the 1941
Figure 31: Portion of a Zeiss color infrared photograph showing the area around Mound A at the Broussard Mounds site. Photo taken at approximately 16:00 UTC on March 10, 1999.
Figure 32: Portion of a Zeiss color infrared photograph showing the area around Mound C at the Broussard Mounds site. Photo taken at approximately 16:00 UTC on March 10, 1999.
Figure 33: Portion of a historic aerial photograph showing the Broussard Mounds site. Photo taken March 1, 1941.
Figure 34: Portion of a historic aerial photograph showing the Broussard Mounds site. Photo is 1:20,000 scale, taken January 11, 1953.
Figure 35: Example of vector layer creation using multiple sources of historic information georeferenced to modern color infrared aerial photography.
Figure 36: Portion of a Zeiss color infrared photograph with vector layers from multiple historic sources added.
aerial photo. No correlations were made between the historic structures and the modern landscape using the color infrared photo. This is quite disappointing given the level of spatial resolution for these photographs.

One anomaly that was of interest near Mound A was an extremely faint elliptical pattern to the south of Mound A, shown in Figure 36. This anomaly could represent some type of prehistoric feature not previously identified at the Broussard Mounds site. However, the alignment of the elliptical anomaly does not seem to be directly related to the mounds, if the location and relationship of the mounds at the Broussard Mounds site is with the New River. The proximity of the potential feature to modern disturbances seems to suggest a more recent origin. For this reason, the anomaly to the south was viewed with skepticism.

One of the initial expectations in analyzing the aerial imagery from the Broussard Mounds site was to identify large anomalies that were not previously recorded, similar to those found by Shuman et al. (1999) at the Taylor Place/McGuffee Mounds site, where the same types of imagery were used from the same flight. Shuman et al. (1999) used the imagery to locate an earthen enclosure surrounding several mounds through visual inspection of color infrared photography and ATLAS data. Although the anomaly south of Mound A does seem to be the best candidate for an earthen enclosure at the Broussard Mounds site, the modern disturbances nearby and the overall ambiguous nature of the identified feature reduce the probability that the anomaly represents a planned, prehistoric embankment.

In addition to the recent work with farm equipment near Mounds A and C, the placement of the gas pipeline that had spawned the 1997 investigations by Surveys Unlimited Research Associates was underway at the time the color infrared photos were taken (Jones et al. 1998). Thus, the area around Mound B was comprised of extremely tall scrub vegetation,
offset by distinct patterns of clearing for access to pipeline work. These patterns are extremely pronounced, and render the area around Mound B even less suited for feature identification through differential vegetative growth and soil stains (Figure 37). No anomalies related to possible unrecorded archaeological features were identified through visual inspection for the area around Mound B.

As another aid in interpretation, the LIDAR data that was downloaded from Atlas: The Louisiana Statewide GIS website was used to create three-dimensional imagery of the Broussard Mounds site. Both the Zeiss color infrared photographs and the LIDAR Digital Elevation Model (DEM) were used to create an interesting visual representation of the site that incorporates sub-meter spatial resolution, two foot digital elevation contours, and the use of infrared reflectance information (Figure 38). Once the LIDAR data were draped with the color infrared photograph, the elliptical feature to the south of Mound A appeared to be aligned in the opposite direction from what was observed in the aerial photos. However, this inconsistency could easily be explained as simply a vegetation change from one data set to the next, or a product of distortion associated with the three dimensional display of the data. In fact, the LIDAR imagery alone is quite intriguing. The contour information that is visible with the LIDAR DEM is phenomenal. This information shows a surprising level of detail for drainages, especially drainages that are not readily discernable from a surface perspective because of the gradual elevation changes at the site. As LIDAR data coverage increases, this information will surely provide archaeologists with new insight into any number of spatial relationships related to landforms within coverage areas.

Also of note, while studying the historic aerial photographs, another possible mound was identified within another bend of the New River to the southwest of Mound B, as shown
Figure 37: Portion of a Zeiss color infrared photograph showing the area around Mound B at the Broussard Mounds site. Photo taken at approximately 16:00 UTC on March 10, 1999.
Figure 38: Three-dimensional recreation viewed from an oblique perspective of the Broussard Mounds site. Image created with LIDAR data and a Zeiss CIR aerial photograph.
in Figures 33 and 34. When the modern photograph was used to relocate this possible mound, it is apparent that activities associated with the expanding borrow pit in this area most likely have destroyed the mound. A pedestrian survey of the area confirmed this fact, as most of the area has been removed down to a level of approximately 10 to 20 cm below ground level. The only areas that are currently intact are portions of the surface located directly under large live oak trees; none of these included possible mound remnants.

However, several prehistoric ceramic sherds were recovered from this location and several areas of fired clay were observed during the survey of this location; one of the sherds was identified as a Mazique Incised, *var. Mazique*, an early Coles Creek type of decoration (Figure 39). This sherd might have an association with the mound, if the observed anomaly was a mound.

35mm Infrared Photography

The 35mm black and white infrared photography shot at the Broussard Mounds site was visually inspected to identify anomalies that might be present on the photos. Seven rolls of 36 exposure black and white infrared film were shot; photographs were taken throughout the site. The photography included shots from areas on and around each of the three mounds.

In general, the method used to photograph areas using the black and white infrared film seems unproductive. Simply standing and shooting does not allow for a consistent shot to be captured. Bracketing the exposures allowed for better photographs, but overexposure and underexposure of the shots was common, most likely do to inconsistent light levels caused by variations in cloud cover. Many shots are slightly too dark or too light, and the photographs with clarity and good contrast in the near field tend to loose that contrast away from the camera. Thus, discerning changes in infrared reflectance gets more difficult the
further the objects are from the camera; this seems to be a product of the camera angle in relation to the ground surface or the depth of field of the exposure. As the vertical perspective is lost, the ability to recognize vegetation patterns in the photographs is decreased. Another, even greater, problem associated with the photographs is the effect of shadows from trees; this was especially problematic at Mound C, where very little information about vegetation or soil patterns can be discerned due to the many shadows cast by the trees around the mound.

Anomalies were identified during the inspection of the black and white infrared photos at Mound A and Mound B. Although there are several distinct vegetation patterns around Mound A, only one was interpreted as being associated with anything archaeological.
in nature. Near the foundation, on top of Mound A, is a square area of vegetation differences (Figures 40 and 41). This area is not under concrete, but appears to be the location of a rear extension of the house, perhaps a porch or stairs, that have subsequently been removed. The possibility exists that this anomaly is associated with an earlier structure, but in all likelihood it belongs to the much later house built on the foundation that is present today. The ability of the black and white imagery to identify areas where houses were once located seems reasonably good, if ground surfaces are fairly undisturbed.

Areas around Mound B exhibited patterns in vegetation as well. Certain circular features are visible on the black and white infrared that coincide with features on the 35mm color infrared photos (Figures 42 and 43). These features are probably related to vehicles making sharp turns in the field while coming to or leaving from the site. Another possible source for these anomalies is tractor turnaround points. Only one amorphous feature near a low spot could not be readily explained, but this feature is probably related to the moisture level increase caused by the neighboring low area.

Color infrared 35mm film was also used at the site. Six rolls of 36-exposure slide film were shot from various locations around each of the mounds. In many cases, the color infrared photos have much better clarity and considerably more contrast, especially in the infrared, than do the black and white photos. These photographs show the drastic difference in the reflectance properties of the vegetation (Figure 44 and 45). However, the same problem associated with the black and white infrared photography occurs with the color infrared photography in terms of the inability to identify differences in vegetation as the vertical perspective is lost in the photographs. The color photos show the same features as the black and white infrared in many cases, but the clarity seems better at greater distances
Figure 40: Black and white infrared photograph showing a possible archaeological feature at Mound A. View is from top of Mound A facing north-northeast. (Photo taken at approximately 3:30 PM local time)

Figure 41: Black and white infrared photograph showing a possible archaeological feature at Mound A. View is from top of Mound A facing north. (Photo taken at approximately 3:30 PM local time)
Figure 42: Black and white infrared photograph showing circular features east of Mound B. View is from top of Mound B facing east. (Photo taken at approximately 3:30 PM local time)

Figure 43: Black and white infrared photograph showing circular features east of Mound B. View is from hunting platform northeast of Mound B facing southwest. (Photo taken at approximately 3:30 PM local time)
Figure 44: Color infrared photograph showing differential reflectance for vegetation. View is from northeast of Mound A facing east toward Mound C on left side of tree line. (Photo taken at approximately 3:30 PM local time)

Figure 45: Color infrared photograph showing differential reflectance for vegetation. View is from northwest of Mound A facing northwest toward New River. (Photo taken at approximately 3:30 PM local time)
than on the black and white. The clarity enables the identification of several spots that are varied in infrared reflectance to the north of Mound A (Figures 46 and 47). These areas are locations where previous structures may have been located. However, no structures were confidently located within this area on the historic aerial photographs. Many other areas, between mounds or under shade or trees, may contain subsurface features expressed through differences in infrared reflectance at the surface. Unfortunately, the amount of film available for this project did not allow for a complete coverage of images from the entire site; thus, many areas remained unphotographed.

Discussion

The acquisition of 35mm infrared photography required a substantial amount of pre-collection testing of camera settings and lighting conditions in order to produce satisfactory photographs. Not only was this a tedious process, but it also required a substantial amount of turn-around time, particularly because of the difficulties involved with getting the film processed. A very limited number of commercial infrared film processing laboratories are available. Since the chemical mixture used for processing infrared film differs from the mixture used for most standard film types, processing facilities schedule film development based on the number of rolls needed to be processed. For instance, Rocky Mountain Film Laboratories, the film developers chosen for the work associated with this research, only process infrared film every six months or when enough infrared film is submitted for processing to make the most efficient use of the chemical mixture. The greatest number of rolls sent at any one time for this research was 13 rolls, and this was not a sufficient quantity to process at once. In addition to processing difficulties, because the color infrared film was slide film, this required the use of a slide scanner for transfer to digital format, a projector,
Figure 46: Color infrared photograph showing differential reflectance for vegetation north of Mound A. View is from Mound A facing north toward Mound B. (Photo taken at approximately 3:30 PM local time)

Figure 47: Color infrared photograph showing differential reflectance for vegetation north of Mound A. View is from Mound A facing north-northeast. (Photo taken at approximately 3:30 PM local time)
or another process by which to analyze the photos. For this project both a slide scanner and projector were used.

In general, the use of 35mm infrared photography was not as productive as was initially hoped. The ability of the film to detect variation in relative health of vegetation is apparent, but many other factors reduce the usefulness for archaeological reconnaissance. However, this research only attempted the most rudimentary application of infrared photography, focusing primarily on its use in a very unrefined collection process. As a point and click tool, infrared photography would seem to have limited efficiency for applications in archaeology; but, if the method were refined more through the use of photography at higher angle perspectives and testing under a wider range of variables such as relative light levels, sun angle, climatic conditions, etc., then the efficiency may be increased.

**ATLAS Imagery**

The ATLAS imagery acquired for this thesis research has been extensively viewed for the presence of anomalies that may represent significant archaeological features. Inspection of the imagery included multiple combinations of the available bands collected by the ATLAS sensor. No potentially significant archaeological features were identified from the imagery with the exception of two anomalies that were visible in the short wave and thermal bands collected by the sensor (bands 7 – 15) (Figures 48-50).

ATLAS data may have identified a feature that was initially located in the GPR data. After the completion of the GPR work at Mound A, excavations were conducted to identify one of the anomalies located on the horizontal slices. The anomaly that was excavated was a buried layer of bricks surrounded by a matrix of gravel and a whole host of other historic items. The location and identification of this feature is discussed in more detail in Chapter 6,
Figure 48: Portion of a ATLAS three band image showing the area around the Broussard Mounds site. Image collected at approximately 16:00 UTC on March 10, 1999.
Figure 49: Portion of a ATLAS single band image showing the area around the Broussard Mounds site. Image collected at approximately 16:00 UTC on March 10, 1999.
Figure 50: Portion of a ATLAS three band image showing the area around Mound A at the Broussard Mounds site. Image collected at approximately 16:00 UTC on March 10, 1999.
along with more information regarding the archaeological materials recovered. However, after the brick feature was identified through excavation, the area on the ATLAS imagery near the location of the test units was reassessed for any possible correlation. At this point, it became apparent that there was a very small area of higher returns on bands 7 through 15 of the ATLAS imagery in the vicinity of the brick feature. One could expect a higher return on these bands for a feature of this size because there was a significant difference in soil mineralogy and differential heat retention. If the brick feature had been heated by solar radiation at a different rate than surrounding soils at the time the imagery was collected, then it is possible that the feature would yield a higher return relative to the surrounding areas of the image. Because of the small size of the brick feature and the 2.5 m resolution of the image, it is difficult to make a clear connection of the apparent anomaly with the observed archaeological feature. Unfortunately, when the GPR data was georeferenced and compared to the ATLAS image, the brick feature did not directly match the area of higher return on the ATLAS imagery (Figure 51).

The second anomaly was a large area of relatively higher return, shown in Figures 48-51, located to the northeast of Mound A. This area is rectangular. The location and size of the high return is consistent with that of a structure on the historic photos. The thermal signature on the ATLAS image suggests that the anomaly is also the result of differential heating and/or cooling associated with the historic structure or some type of activity relating to the use of this structure.

ATLAS imagery, although capable of recording a greater amount of spectral information than the color infrared photography, has a spatial resolution that is not sufficient for visually identifying small archaeological features. The identification of most features
Figure 51: Portion of a ATLAS three band image showing GPR time slice data and vector layers of historic features near Mound A at the Broussard Mounds site.
requires the ability to discern shapes that relate to cultural features; this is not possible, in most cases, if the resolution is 2.5m. However, the spectral properties of some features may create overlap with neighboring pixels when sampled, due to extremely high or low values, allowing shapes to be identified even if the spatial resolution, theoretically, is not capable of producing the patterns independently. For this project, and in most prehistoric contexts, ATLAS imagery that is only analyzed through visual interpretation has minimal value as a tool for identifying small features, but larger features such as embankments or the buried remains of large historic structures would be easier to locate. This research was limited to visual inspection of the ATLAS imagery. However, if land-cover classification had been used for spectral values related to known archaeological features or areas that were suspected to contain archaeological remains, then perhaps additional areas would have been identified as possible locations for buried archaeological features. The greatest potential use of ATLAS imagery in the future may be in the establishment of spectral classes associated with confirmed archaeological features. These classes could be used to locate intra-site features similar in nature to the features with established classes. If features can be located in situ, then associated spectral signatures may also be useful as reference for similar features at other sites. This type of in-depth analysis will require a much greater amount of research—using ATLAS imagery at a large number of archaeological sites—before this potential is realized.

**Ground Penetrating Radar**

The ground penetrating radar work that was completed at the Broussard Mounds site was the most useful remote sensing data collected for direct archaeological comparison. At Mound A, horizontal slices showed the location of several anomalies. One of these
anomalies was a large circular reflection, located approximately 50 m north and 24 m east of the datum atop Mound A; another large anomaly was located 70 m to the north (Figure 52). The anomaly at 50N, 24E was investigated through archaeological excavations, and was determined to be the buried remnant of an unidentified brick feature. The results of these archaeological investigations are discussed in Chapter 6. Another location near Mound A at 80N, 15W was investigated through a series of shovel tests that were placed in the vicinity of another anomaly that suggested an archaeological feature. However, this anomaly, located along the entire western portion of the survey area at 10W to 20W and 50N to 100N was interpreted as a disused but modern roadbed after comparison with aerial data and inconclusive results from the shovel tests.

The data processing for Mound A utilized the GPR Process software to create horizontal time slices of the data collected over the 70 m x 50 m area north of the mound. Several difficulties were encountered during the processing phase. The transect spacing was too wide to accurately identify small anomalies within the area surveyed; this also made details of larger features less discreet. Other problems included the inappropriate setting of gain points with increased depth of investigation, the erroneous inclusion of a RDP at Mound A based on a reading taken earlier at Mound B, and the absence of user marks in the data set. GPR Process requires the use of user marks that are placed at known intervals associated with surface measurements along each transect. This allows the GPR transects to be aligned, re-sampled and then sliced horizontally. If the user marks are not present, then marks have to be added during processing, and surface distances are approximated. Adding user marks, in this fashion creates a data set that may not be aligned correctly if transects were collected at different foot speeds. However, in most cases, foot speeds do not vary drastically enough
Figure 52: GPR horizontal time slices for area surveyed at Mound A. Each slice from 1 to 6 represents approximately 10cm.
to cause a significant offset between transects; but the time required to manually adjust the user marks is significant. Adding user marks becomes extremely laborious, even if shortcuts are taken, such as the use of an Excel spreadsheet with predefined formulas for acquiring the file location for the entry of user marks. Once the file location is found, each GPR transect file has to be edited with at least four marks placed at equidistant points in the data.

Just as the data was not efficiently collected at Mound A, the data from Mound B (collected earlier than the Mound A data) was problematic in the same ways, save for the fact that an actual RDP value was calculated nearby and the data were collected as 8-bit data instead of 16-bit data. The use of 8-bit data may have limited the amount of detail in the data because of the decrease in information collected. Mound B data was additionally challenging during processing because the alignment of transects was different from one area of Mound B to another. Mound B data was initially analyzed using only RADAN to identify anomalies within vertical profiles because the setup and survey methods used made the rendering of horizontal time slices all but impossible to achieve. However, a 10 m² from the grid cell was eventually processed using GPR Process for comparison with the vertical interpretation. Several possible anomalies were located using the vertical profiles. To be considered significant, each anomaly must have been continuous across at least two transects. Once the most obvious anomalies were plotted, a decision was made to excavate two that were located in proximity to Mound B. These two anomalies were also near previous investigations and were near an area that reportedly contained midden deposits (Figures 53 and 54). Both were located just to the northeast of Mound B. At least two well-defined prehistoric cultural layers were excavated in each of the test units. Unfortunately, one of the test units contained a large modern root that was located within the best defined (in terms of GPR resolution) of the
cultural layers; thus, questions were raised as to what was actually identified by the GPR, the cultural layer or the root.

Mound C GPR data was collected exactly like Mound A only the area surveyed was smaller. The same data collection problems were present as well. At Mound C, several anomalies were identified in the horizontal time slices (Figure 55). Five of the anomalies identified were investigated using shovel tests. The anomalies selected for investigation were chosen based on highest reflection values. None of the anomalies investigated were determined to be archaeological in nature. Several of the anomalies may have been associated with mineral concretions that were encountered during excavation. These shovel tests are discussed in more detail in Chapter 6.

Summary

In all, the investigations associated with the anomalies located using GPR led to the identification of five archaeological features. Only three significant anomalies were noted for the GPR slices at Mound A. Of these three anomalies, only one was thoroughly investigated. Two 1 x 2 m test units revealed a historic brick feature. One of the other anomalies identified at Mound A was investigated to a lesser extent using five shovel tests. Several anomalies were located in the GPR transects collected near Mound B; two were tested. The excavations at Mound B identified at least two different cultural layers within each test unit. These cultural layers had a questionable association to separate horizontal anomalies identified in the GPR data. Although several anomalies were also located at Mound C, shovel test excavations were only placed over five of the anomalies; no cultural remains were found in the areas excavated.
Figure 53: GPR vertical profile images of transects in vicinity of the test units at Mound B. Note corresponding features across each profile.
Figure 54: GPR horizontal time slices for 10 m area near the two test units placed at Mound B. Each slice from 1 to 10 represents approximately 10cm.
Figure 55: GPR horizontal time slices for area surveyed at Mound C. Each slice from 1 to 6 represents approximately 10cm.
Ground penetrating radar was by far the most complicated of the techniques used at the Broussard Mounds site. Simply having an understanding of how GPR data is collected and processed does not allow for effective use of the technology. The SIR System-2 control unit has many different parameters that can be tweaked during setup. This makes the decision-making process with regard to optimizing settings for best results very difficult; different soils, moisture levels, ground cover, etc. can require different settings. Usually, the usefulness of the information collected may not be fully known until it is processed; and then, even after excavation, correlations between anomalies and observed phenomena are often difficult. Fortunately, as new software becomes available, making associations between GPR data and actual archaeological features will become increasingly more efficient.
 CHAPTER 6:  
ARCHAEOLOGICAL INVESTIGATIONS

Excavations to identify subsurface anomalies located using remote sensing methods were begun at Mound B on March 10, 2001. Both of the two test units excavated at Mound B for this research project (69N 01E and 65N 07E) were excavated to a depth of 120 cm below each unit datum (northwest corner). Subsequently, a 50 cm wide test trench was excavated in both units along the wall opposite the OCR column sample areas; this trench was excavated to a depth of 200 cm bd. The original expectation was that the upper-most anomaly located in the GPR profiles at Mound B would likely be the late Marksville midden deposit excavated in test units during the two earlier projects conducted by Surveys Unlimited Research Associates (Shuman et al. 1995; Jones et al. 1998). Anomalies located deeper in the profiles were hypothesized to represent additional occupation layers or stratified episodes of mound construction.

The soils encountered at Mound B, alluded to in Chapter 4, were difficult to separate stratigraphically because of their homogeneity. Most of the strata within the excavations were comprised of nearly equal parts of sand and silt (approximately 30% - 50%), and contained enough clay (approximately 10% - 30%) to be classified as loam. The Munsell hue of all soils (except the darker lenses of concentrated cultural material) was 10YR, with Values ranging only from 4 to 5 and a Chroma range from 1 to 3. Interpreting these slight variations while in the field was nearly impossible. However, during excavations, variation was noted in terms of the relative amounts of sand and silt that could be identified through textural differences (Figures 56-59). Unfortunately, no areas of basket loading were identified; because of this, no mound construction strata were confirmed. All of these soils
Figure 56: North wall profile of Test Unit 69N 01E.
Figure 57: East wall profile of Test Unit 69N 01E. Refer to Figure 56 for key and scale.

Figure 58: South wall profile of Test Unit 69N 01E. Refer to Figure 56 for key and scale.
could be natural primary alluvial deposits or secondary—culturally transported—deposits of that same alluvium. In general, except where plowed, these strata were extremely low in artifacts. If some of these strata were indeed mound fill, then little occupational debris was present in the borrow area.

The excavations at Mound B yielded a good deal of archaeological material. However, the identification of the anomalies near Mound B was not as easy as was hoped. Several subsurface features, both of natural and human origin, were identified during the excavations. In the first test unit to be completely excavated at Mound B (69N 01E), a large root was encountered near a sloping interface and near the location of numerous large ceramic sherds within a stratum of cultural material (Figures 60 and 61). These items were all encountered in the proximity of a location where the GPR indicated a promising anomaly.
Figure 60: Photograph of Test Unit 69N 01E showing large root encountered in the proximity of Feature 1. Feature 1 is the darker area through center of test unit.

Figure 61: Photograph of north wall profile of Test Unit 69N 01E.
Unfortunately, a clear determination of what caused the anomalous return cannot be made, but there is a strong correlation between the locations of horizontally aligned anomalies on the GPR profiles and stratigraphic layers of cultural deposits encountered in excavations. The same is true with excavations from (65N 07E), the second test unit completed at Mound B.

**Test Unit 69N 01E**

Excavations in 69N 01E revealed a buried surface with a considerable amount of cultural remains that was first identified in Level 5 and continued along a slope down to Level 10 (Figures 56-63). This cultural zone was first called Feature 1, but could also be referred to as a stratum because it appears to be present in both test units excavated. On the west side of the test unit the feature was encountered at 40 – 50 cm below datum; this agrees with the location for an anomaly on most of the GPR profiles in the vicinity. Feature 1 is without a doubt the most substantial subsurface archaeological feature located during the excavations at Mound B. The feature is comprised of very dark clayey loam earth midden. Numerous bone fragments, charcoal, fired clay fragments, a few pieces of chert and quartzite lithic debitage, and many prehistoric ceramic sherds were encountered in this stratum. Among the lithic materials recovered from Feature 1 in 69N 01E was a single Kent bifacial tool recovered from Level 10 (Figure 64).

The ceramics recovered from Feature 1 were different from those recovered in earlier excavations at the site, in which a later Marksville component was recorded (Shuman et al. 1995; Jones et al. 1998). The overwhelming majority of sherds recovered from Feature 1 and other proveniences during testing for this project suggest primarily an early Marksville occupation. The most frequently occurring Marksville varieties for both incised and stamped
Figure 62: Photograph of Test Unit 69N 01E showing Feature 1 - Level 8. Note refuse area where a Marksville Incised, var. Prairie sherd was recovered with assayed radiocarbon sample.

Figure 63: Photograph of south wall profile of Test Unit 69N 01E.
ceramics from Feature 1 were var. Marksville, with a few occurrences of varieties Prairie and Sunflower for the incised types, and Old River for the stamped (Figures 65-67; Table 9). All of these are considered early varieties of Marksville Ceramic types of the Smithfield Phase (Phillips 1970; Toth 1974; 1988).

The presence of an early Marksville component is also corroborated by a conventional radiocarbon date of 1795 +/- 51 B.P. from a sample recovered from Feature 1, Level 8 (Table 10 and Appendix) (Wk-11768). The radiocarbon sample was comprised of charcoal from one gallon of flotation sample that was in direct association with a large articulated Marksville Incised, var. Prairie ceramic sherd (Figure 66a) in a shallow depression within, and extending to just below, Feature 1. This depression was very shallow, appearing simply as a minor undulation in Feature 1 (Figures 61 and 62). The charred plant material from this sample appeared to be a ring-porous wood, possibly nutshell. The flotation sample also contained small bird bones and possibly pieces of turtle carapace. The
Figure 65: Sherds recovered from Test Unit 69N 01E. All sherds in image are Marksville Stamped, var. Marksville.
Figure 67: Sherds recovered from Test Unit 69N 01E: a-c) Vertical Incised and Cross-hatched Marksville rims. d) Marksville Stamped, var. Old River.
Table 9: Ceramics recovered from Test Unit 69N 01E.

| Feature | Ceramic Type | 0-10 cm | 10-20 cm | 20-30 cm | 30-40 cm | 40-50 cm | 50-60 cm | 60-70 cm | 70-80 cm | 80-90 cm | 90-100 cm | 100-110 cm | 110-120 cm | 120-130 cm | Total
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<tr>
<td>69N 01E</td>
<td>Ceramic Type</td>
<td>0-10 cm</td>
<td>10-20 cm</td>
<td>20-30 cm</td>
<td>30-40 cm</td>
<td>40-50 cm</td>
<td>50-60 cm</td>
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Legend:
- Maricopa
- Maricopa Indented
- Maricopa Cross-Hatched
- Maricopa Dotted
- Maricopa Stamped
- Maricopa Incised
- Maricopa Cross-Hatched Incised
- Maricopa Incised Incised
- Maricopa Cross-Hatched Incised Incised
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Table 10: Radiocarbon assays for samples collected at Mound B.

<table>
<thead>
<tr>
<th>Provenience</th>
<th>Laboratory No.</th>
<th>Material dated</th>
<th>Conventional radiocarbon agea</th>
<th>Calibrated 1-sigma rangeb (68.2%)c</th>
<th>Calibrated 2-sigma rangeb (95.4%)c</th>
</tr>
</thead>
<tbody>
<tr>
<td>69N 01E Feature 1 Level 7</td>
<td>Wk-11766</td>
<td>Charcoal</td>
<td>2764 ± 66 BP (13C=-26.5)</td>
<td>1000BC - 990BC (1.4%) 980BC - 830BC (66.8%)</td>
<td>1080BC - 800BC</td>
</tr>
<tr>
<td>69N 01E Feature 1 Level 8</td>
<td>Wk-11768</td>
<td>Charcoal</td>
<td>1795 ± 51 BP (13C=-26.3)</td>
<td>130AD - 260AD (54.7%) 280AD - 290AD (3.0%) 300AD - 30AD (10.5%)</td>
<td>80AD - 110AD (1.9%) 120AD - 390AD (93.5%)</td>
</tr>
<tr>
<td>69N 01E Feature 2 Level 11</td>
<td>Wk-11763</td>
<td>Charcoal</td>
<td>1990± 54 BP (13C=-26.7)</td>
<td>50BC - 80AD</td>
<td>160BC - 130BC (1.7%) 120BC - 130AD (93.7%)</td>
</tr>
<tr>
<td>69N 01E Feature 2 Level 11</td>
<td>Wk-11767</td>
<td>Charcoal</td>
<td>1805 ± 50 BP (13C=-26.2)</td>
<td>130AD - 260AD (61.8%) 300AD - 320AD (6.4%)</td>
<td>80AD - 350AD</td>
</tr>
<tr>
<td>65N 07E Stratum 12 Level 10</td>
<td>Wk-11765</td>
<td>Charcoal</td>
<td>1858 ± 55 BP (13C=-27.7)</td>
<td>80AD - 110AD (9.4%) 120AD - 240AD (58.8%)</td>
<td>20AD - 260AD (90.8%) 280AD - 330AD (4.6%)</td>
</tr>
<tr>
<td>65N 07E Stratum 12 Level 11</td>
<td>Wk-11764</td>
<td>Charcoal</td>
<td>1902 ± 53 BP (13C=-27.6)</td>
<td>20AD - 140AD (53.2%) 150AD - 180AD (8.0%) 190AD - 220AD (7.0%)</td>
<td>0 - 240AD</td>
</tr>
</tbody>
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a based on the Libby half-life of 5568 yr with correction for isotopic fractionation applied.

b The University of Waikato Radiocarbon Dating Laboratory probability calibrations using atmospheric data from Stuiver et al. (1998); OxCal v3.5 Bronk Ramsey (2000); cub r:4 sd:12 prob usp[chron]

c Total probability of sample
sample material was interpreted as being campfire refuse (Standifer, personal communication, 2002). Unfortunately, another sample from Feature 1, Level 7 was dated to 2764 +/- 66 B.P. (Table 10 and Appendix) (Wk-11766). This earlier date is probably the result of admixture from naturally occurring carbonized materials at the time the site was occupied.

Another thin occupational lens was encountered at 90 – 100 cm below datum within Level 10 and continued to 110 cm at the base of Level 11. This stratum was referred to as Feature 2, but, like Feature 1, it may also be called a stratum because of its horizontal extent—similar materials at the same depth occurred within portions of 65N 07E (Figures 61, 63, and 68). Feature 2 contained material similar to Feature 1, but the material was not as concentrated and did not contain as many ceramics. Although the decorated ceramics from this stratum are sparse, a single Marksville Incised, var. Marksville ceramic sherd was recovered, suggesting an early Marksville association for Feature 2 as well. This early Marksville association for Feature 2 is corroborated by two radiocarbon samples, both taken from bulk flotation samples in Level 11, with dates of 1990 +/- 54 B.P. and 1805 +/- 50 B.P. (Table 10 and Appendix) (Wk-11763; Wk-11767). Feature 2 contained some lithic debitage, bone, fired clay, and several undecorated ceramic sherds.

The majority of the ceramic artifacts recovered from Test Unit 69N 01E was recovered from Feature 1. A graphical comparison of the ceramics recovered from Feature 1 and Feature 2 with the other proveniences within Test Unit 69N 01E is shown in Figures 69-73. The relative abundance of ceramics, especially decorated ceramics, from Feature 1 is quite apparent. Most of the ceramics recovered in 69N 01E were undecorated. Marksville Stamped, var. Marksville is the most frequently occurring decorative treatment. Marksville
Figure 68: Photograph of Test Unit 69N 01E showing Feature 2 in Level 10.

Figure 69: Graphic showing the relative number of sherds per level within Test Unit 69N 01E.
Figure 70: Graphic showing the relative number of sherds from Features 1 and 2 within Test Unit 69N 01E.

Figure 71: Graphic showing the relative number of decorated sherds from Features 1 and 2 within Test Unit 69N 01E.
Figure 72: Graphic showing the percentage of decorated sherds from Features 1 and 2 within Test Unit 69N 01E.

Figure 73: Graphic showing the relative number of Marksville ceramic varieties from Features 1 and 2 within Test Unit 69N 01E.
Incised, *Marksville* is the second most common variety, not including unspecified varieties of Marksville incised sherds.

**Test Unit 65N 07E**

The excavation of 65N 07E revealed a cultural stratum, Stratum 2, at 20 cm below datum, at the beginning of Level 3 and extending to just over 40 cm below datum at the top of Level 5. This stratum was slightly darker than the soils from the overlying levels (Figures 74-78). Aboriginal ceramics increased with depth and were most numerous within Stratum 2. Though this stratum was not as well defined as Feature 1 in Test Unit 69N 01E—it was not as dark, possibly because it had been mixed with overlying soils by plowing—it was initially considered the same deposit. With additional excavation, however, it became clear that this was a separate stratum from either of the two primary cultural zones encountered in 69N 01E. Also, it should be noted that this stratum is most likely the uppermost anomaly located by the GPR in the profiles collected in the location of the test units.

In addition to lithic debitage and prehistoric ceramics, this stratum also contained brick, iron, and gravel (as did the upper levels) related to the historic component at the site. The prehistoric ceramics recovered from this stratum are primarily undecorated, but the two decorated sherds identified are Coles Creek, *var. Hardy* and Larto Red, *var. unspecified*. The *var. Hardy* sherd, and to a lesser extent the Larto Red, indicate a later occupation at the Broussard Mounds site, which is not too surprising given the Alba point recovered during excavations by Jones et al. (1998). There was no evidence of this later occupation in 69N 01E.

A more prominent cultural stratum, Stratum 8, was encountered at 60 – 70 cm below datum in Level 7 and continued to the bottom of Level 10, ending at about one meter in
Figure 74: North wall profile from Test Unit 65N 07E.

Figure 75: East wall profile from Test Unit 65N 07E. Refer to Figure 74 for key and scale (see Figure 76 for Strata 6).
Figure 76: South wall profile from Test Unit 65N 07E.
Figure 77: West wall profile from Test Unit 65N 07E. Refer to Figure 74 for key and scale (see Figure 76 for Strata 6).

Figure 78: Photograph of Test Unit 65N 07E showing north wall profile. (profile shot taken following unit inundation from Tropical Storm Allison).
depth along the extreme southern side of the test unit in the southwest corner (Figure 74-79). This stratum was dark (10YR3/2) loam that contained charcoal, lithic debitage, fired clay, and ceramic sherds. A layer of harder, compacted soil was encountered just before this stratum was reached and was often intermixed with the darker stratum. The consistency of the harder packed layer, along with sherds that were consistently turned at vertical angles, may indicate that this layer was a clay cap related to mound construction.

After vertically aligning the two units based on transit elevations, it was clear that this stratum is located at the same elevation as the east side of Feature 1 in 69N 01E. These cultural lenses are probably related to the same depositional event. A hypothetical stratigraphic profile that includes the 4 m unexcavated space between the two test units is useful for showing the relationship between strata (Figure 80). Stratum 8, combined with the
Figure 80: Idealized profile showing stratigraphy at Mound B. (Strata are hypothetical; refer to Figures 56, 58, and 74 for cross references to soils)
associated hard packed stratum, is the most likely candidate for being the deepest cultural anomaly identified with the GPR over the location of the test units.

The ceramic sherds recovered from Stratum 8 in 65N 07E were fewer in number than in Feature 1 in 69N 01E, but were also all early Marksville types (Table 11). Only four sherds from Stratum 8 could be identified to variety, two crossmending Marksville Incised, var. Prairie, one Marksville Incised, var. Marksville, and one Mabin Stamped, var. Mabin rim. Two other sherds were identified as Marksville Stamped, var. unspecified, one Marksville Incised, var. unspecified, and one Marksville cross-hatched rim. The Mabin Stamped, var. Mabin sherd from Stratum 8 was categorized on the basis of a very small area of dentate stamping. This sherd could also be Marksville Stamped, var. Marksville, but, based on the limited decorative treatment, it more closely matched the var. Mabin category.

At almost 100 cm below datum in the northeast corner of this unit, a lens of charcoal, approximately 10 cm in depth, was encountered (Figures 74, 75, and 81). Only a small portion of this charcoal lens was exposed in the unit; a considerable amount remains in situ. However, an additional 50 cm² was removed in the OCR column. Two radiocarbon samples taken from this area yielded dates of 1902 +/- 53 B.P. and 1858 +/- 55 B.P. (Table 10 and Appendix) (Wk-11764; Wk-11765). Samples taken from the charcoal were comprised exclusively of cane, Arundinaria gigantea, and a few small bone fragments. The cane was interpreted by Standifer as refuse related to the processing of basketry or matting (Standifer, personal communication, 2002). The association of this area of carbonized cane with surrounding strata and strata from 69N 01E is unclear. The concentration of cane was located within Stratum 12, but was most prominent in the northeast corner of the unit. Stratum 12 was another thin lens with scattered charred organic material like Feature 1. The
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<td>46</td>
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carbonized cane and Stratum 12 appear to be related to Feature 2 in 69N 01E. Like Feature 1 and Stratum 8, these two cultural lenses were located at approximately the same depth.

Both Feature 2 and Stratum 12 are lenses containing concentrations of charred material (i.e., charred bone fragments and charcoal from cane and other sources). Continuous or not across the unexcavated area between the two test units, both lenses are related to some similar unknown activity that occurred at roughly the same time. Pottery in the two areas is early Marksville. No artifacts were found in the area of carbonized cane, but Stratum 12 contained seven diagnostic Marksville ceramic sherds, three were Marksville Incised, *var. unspecified*, three were Marksville Stamped, *var. unspecified*, and one was a Marksville cross-hatched rim sherd. In addition, the dates from the two radiocarbon samples from the cane and two radiocarbon samples from Feature 2 in 69N 01E were very similar,

Figure 81: Photograph of charcoal (carbonized cane), part of Stratum 12 in Northeast corner of Test Unit 65N 07E at Level 11.
strongly suggesting that Strata 12 and Feature 2 may be the same age (Table 10 and Appendix).

Finally, another noteworthy stratum was encountered within the trench along the south wall (Figures 76 and 82). At 144 to 154 cm below datum in the trench, another dark organic lens, Stratum 15, was encountered. This lens extended from the southeast corner horizontally along the south wall to just over one meter to the west, or half-way across the profile. Two diagnostic sherds were recovered from this lens; one was identified as Larto Red, var. Long Lake and the other was Marksville Stamped, var. Marksville. Needless to say, the depth of this lens and the irrefutable Marksville association were quite surprising. The lens was photographed and added to the south wall profile, but not given further investigation because of time constraints and the difficulties involved with the water table within the trench.

Discussion

The two most prominent cultural lenses that were excavated in the test units at Mound B, Feature 1/Stratum 8 and Feature 2/Stratum 12, have several characteristics in common with other Marksville sites excavated in the Lower Mississippi Valley. The most pronounced deposit, Feature 1, contained many areas of burned bone and charcoal, as did other pockets throughout the test units; these are similar to areas within mound contexts at Marksville and Crooks (Ford and Willey 1940). Also, the area of charred cane located in 65N 07E indicates that cane matting or basketry may have been used within the mound context, as at both Marksville and Crooks (Ford and Willey 1940; Toth 1988). Although no definitive "status-related" (Toth 1988: 50-1) items were recovered, the majority of the ceramics recovered are decorated in classic Marksville motifs and styles, and given the dates derived from the
radiocarbon samples collected during this research, there is no reason to doubt that if further excavation was conducted, many if not all, of the attributes associated with other Marksville sites in Louisiana would be recovered at Mound B.

Given the ceramic assemblage recovered from the test units at Mound B, it was concluded that, contrary to earlier findings by Shuman et al. (1995) and Jones et al. (1998) of an association with the Gunboat Landing Phase site, the primary occupation of the Mound B area was the Smithfield Phase of the early Marksville Period. However, other areas not excavated during this research could yield a greater abundance of later artifacts that are related to the Gunboat Landing Phase. There is evidence from 65N 07E to support a later occupation during the Coles Creek Period (A.D. 700 -1200), although this occupation was
not as significant as the earlier component. Based on this research, site use, and perhaps mound construction, at Mound B is associated with an early Marksville occupation; most likely attributable to the Smithfield Phase of the early portion of this period.

**Mound A**

Excavations to identify two of the anomalies located through the use of the GPR at Mound A began on September 7, 2001. Two 1 x 2 m test units were excavated; these test units were placed end to end to produce a 1 x 4 m continuous excavation from 50N - 51N and 22E - 26E. Additionally, five shovel tests were placed in an area selected as containing another anomaly. These shovel tests were placed at 1 m intervals in a cruciform pattern centered at 80N, 15W. Seven additional shovel tests were placed at 30 m intervals around the northern half of Mound A (Figure 28). The two test units were excavated to a depth of 90 cm, at which depth the water level had become unmanageable and the excavation was stopped. Each of the shovel tests was excavated to varying depths, continuing as deeply as possible depending on the conditions.

On the basis of the knowledge that several structures were previously located in the area, and because of the overall intensity and shape of the GPR return, it was expected that the anomaly tested in the two units at Mound A would be some type of historic structure. This was the case, although very little of the structure remained intact due to plowing or some other modern activity. The second area, excavated through shovel testing, was initially thought to be associated in some way either with the modern field road and/or with previous roads. However, there was hope that this area could also be related to another structure that may have been in the area. Although not confirmed, the shovel tests indicated that the initial interpretation for the anomaly reflecting some type of field road was most likely, as no
evidence of a structure was recovered. No confirmation that the anomaly indicated a field road is possible, however, because of the very small numbers of associated artifacts, the small areas of excavation, and nature of the suspected feature. The shovel tests that were placed around the north side of Mound A contained numerous historic artifacts, but there was no evidence of prehistoric occupation.

**Test Unit Excavations**

The test unit excavations at Mound A uncovered an abundance of gravel and shell, along with a wide assortment of modern materials, mixed with brick, nails, and other late nineteenth century and early twentieth century artifacts. Materials recovered from the top two levels and into Level 3 showed signs of considerable disturbance from modern activities at the site. Although care was taken to separate the various stratigraphic areas during excavation, these areas will be simplified for this discussion. Areas of disturbance have been combined for discussion purposes in order to focus on portions of the test units that are more intact. Once excavations were into Level 3 in both test units, the integrity of the observed strata became greater. An area of partially intact brick and mortar was encountered in Level 4 (Figures 83 and 84). However, the amount of brick and mortar that remained undisturbed by modern activity was minimal in comparison to what was probably once at the location. Below this feature were undisturbed soils. These included a circular area of charcoal surrounding a small circular brick and mortar feature (Feature 4) in Level 5. It is unclear if Feature 4 was deposited as the result of an activity associated with the brick structure above or if it had been deposited earlier; it most likely predated the brick structure, but the artifacts do not confirm this. A discussion of each of these areas is presented below.
The uppermost portions of the excavations within the two test units showed considerable disturbance and have been grouped together as "Overburden" (Figures 85 and 86). The Overburden was removed to reveal four separate strata within Level 3. These strata were well defined by fairly abrupt changes in soils and/or associated fill (Figures 87 and 88). The strata within Level 3 were grouped together under the category of "Partially Intact"
Figure 85: North wall profile of Test Unit 1.

Figure 86: North wall profile of Test Unit 2
Figure 87: Plan view of Test Units 1 and 2 at Mound A showing Level 3; "Partially Intact" and "Fairly Intact."
Figure 88: Photograph of Level 3 showing the "Partially Intact" area in Test Units 1 and 2 at Mound A.
based on the ability to discern linear patterns. Area 2 (later re-defined as Feature 2) within the Partially Intact portion of the test unit was a dark colored soil overlying brick and mortar below. Area 3 was filled with numerous gravel pieces and had the appearance of a drip-line, perhaps associated with the structure indicated by Area 2 and the underlying brick and mortar. Between Area 2 and Area 3 was Stratum 3 (North), a stratum interpreted to be the undisturbed matrix between the brick structure and the associated drip-line. A similar stratum was identified outside the possible drip-line. This stratum was labeled Stratum 3 (South) and is believed to contain material from outside of the drip-line.

Once the "Partially Intact" areas were removed, the portion categorized as "Fairly Intact" was encountered near the base of Level 3 (Figures 87, 89, and 90). The "Fairly Intact" category was assigned to strata at this depth because of their intact nature, but since the brick and mortar that was encountered within Feature 2 at this level was fragmented, the material had probably been subjected to modern plowing. The strata at this depth were fairly consistent with overlying strata. Feature 1 was an area comprised almost entirely of gravel pieces, but was much better defined than the overlying area of gravel that was labeled Area 3. Feature 2, the area of brick and mortar, was encountered directly under Area 2 along the north walls of the units. As noted above, the better resolution of this area prompted redefinition of Area 2. The area of the units labeled Stratum 3 (North) remained, although Stratum 3 (South), at least in Test Unit 2, disappeared to reveal Stratum 4. Stratum 4 contained soil that was more homogeneous and contained substantially fewer artifacts than the overlying Stratum 3 (South), but it too was located entirely outside of Feature 1. Also, within Feature 2 was a small area, Area 4, where the brick and mortar had been disturbed to a greater extent than the rest of Feature 2. As Level 4 was being excavated, Feature 1
Figure 89: Plan view of Test Units 1 and 2 at Mound A showing Level 4; "Fairly Intact" and "Under Brick Feature."
Figure 90: Photograph of Level 4 showing the "Fairly Intact" area in Test Units 1 and 2 at Mound A.
disappeared to show small areas directly below the gravel that contained variations in soils in swirled patterns (Figures 89 and 90). These areas were interpreted as being water marked soils; these occurred below the gravel, at the base of the drip-line. The integrity of the brick and mortar within Feature 2 increased, but only a small portion of the feature remained. This Feature was renamed Feature 3 once the brick and mortar became more intact. Feature 3 appeared before the bottom of Level 4 was reached. Stratum 4 was re-labeled Area 4, as it was similar in color and consistency with the area previously labeled as Area 4.

Material from the base of Level 4 and below was grouped together as being "Under Brick Structure" (Figures 89, 91, and 92). These strata were interpreted as undisturbed by modern activity because the very base of Feature 3, the brick and mortar remains, appeared to be intact. Three major areas were identified at the base of Level 4: Feature 3, the intact brick and mortar; Area 4, the general soil matrix within the test units; and Area 5, patches of lighter colored soils within Area 4. These soils were excavated to reveal an abrupt change in color below Area 4; this underlying area was called Area 6. In the eastern half of Test Unit 1, Feature 4 was encountered below Feature 3 in Level 5. Feature 4 was a circular area, approximately 80 cm in diameter, comprised of charcoal, a few historic artifacts, and numerous bone fragments. In the center of Feature 4 was a small circular area, approximately 30 cm in diameter, containing brick and mortar fragments. No clear interpretation was made as to the function of this feature, but the numerous faunal remains along with the abundance of charcoal seems to indicate some type of food preparation area or trash pit.

The historic ceramics and other materials recovered within the test units point towards a late nineteenth century and/or early twentieth century association. This association
Figure 91: Plan view of Test Unit 1 at Mound A showing Level 5. "Under Brick Structure"

Figure 92: Photograph of Level 5 showing the "Under Brick Structure" area in Test Units 1 and 2 at Mound A.
includes the brick structure and underlying burned feature excavated in the test units. No significant variation in historic ceramics or any other material, outside of modern items such as plastics, was observed between areas considered disturbed and those that were primarily intact.

The historic ceramic assemblage from these test units was comprised of similar types throughout (Table 12). This makes the brick feature difficult to definitively date, outside of the general association with the late nineteenth century and/or early twentieth century. However, these dates are to be expected of any structure that might be located in this vicinity, given the history of the site and the observations made from the historic aerial photography for the area.

Within the two test units at Mound A there was also minute evidence for a prehistoric occupation. Although a prehistoric component was not confidently identified at Mound A, the presence of several lithic artifacts and a podal support (Table 13) suggest that there may be either a very small scale prehistoric occupation, or that the evidence of more intensive occupation is much deeper than the base of the two test units. The latter is more likely given the amount of alluvial deposition at the site. It is also possible that the primary occupation and construction for Mound A occurred during the Archaic Period. This possibility is further strengthened by the greater distance of Mound A to the modern channel of the New River when compared to other older channels that can be observed using the LIDAR DEM (Figure 18). Thus, Mound A may have been constructed along the Bayou Francois/New River drainage at a time when the major channel was closer to the location of the mound. Although this idea is only a hypothesis at this point, it remains a possibility; one that should be tested in the future. Two other prehistoric artifacts were also recovered at Mound A. A single,
Table 12: Historic ceramic sherds recovered from test unit excavations at Mound A.

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<th>Fairly Intact Portion</th>
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<td>Inside Drape</td>
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Table 13: Lithics recovered from test unit excavations at Mound A.

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<th>Level 3</th>
<th>Level 4</th>
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grog tempered pottery podal support was recovered from the overburden in Test Unit 1 in the top half of Level 3. Given the disturbed historic context, the most likely explanation for the presence of the podal support is that it was once part of a personal collection associated with one of the historic structures that was near Mound A, or it was associated with the mound, but was mixed with a later occupation through plowing. The other artifact was a greenstone celt that was recovered from the surface of Mound A (Figure 93). Unfortunately, the celt is not diagnostic.

![Greenstone celt recovered from the surface of Mound A.](image)

**Figure 93: Greenstone celt recovered from the surface of Mound A.**

**Shovel Tests**

In addition to the two test units at Mound A, five shovel tests were excavated at one meter intervals over a portion of another anomaly identified with the GPR (Figure 94). These shovel tests were centered at 80N, 15W, with one shovel test placed at this grid...
Figure 94: Shovel test profiles from area centered at 80N 15W North of Mound A.
location and four others were placed in each cardinal direction one meter from the center shovel test. These shovel tests did not encounter any substantial archaeological feature. They yielded only a few historic artifacts and nothing related to a prehistoric occupation.

Seven additional shovel tests were placed at 30 m intervals around the northern half of the Mound A. As might be expected, several historic artifacts were recovered from these tests, but they did not yield any additional information on the prehistoric occupation at Mound A or any insight into the construction of the mound. Perhaps information regarding the prehistoric occupation and mound construction remains deeply buried by alluvium, out of reach of standard shovel tests like the ones used during this investigation.

**Mound C**

In order to test several anomalies identified through the use of GPR at Mound C, a decision was made to use 30 cm² shovel tests over areas where anomalies were located. Five shovel tests were placed in various grid locations to the northwest of the mound (Figure 95). These shovel tests did not encounter any prehistoric remains. The only artifacts recovered were a few brick fragments from one of the shovel tests. The GPR returns were most likely associated with natural strata. Numerous calcite and manganese concretions were recovered from the shovel tests; it may be that the areas tested contained higher concentrations of these concretions than the surrounding areas.

During the entire project, only a single undecorated prehistoric ceramic sherd was recovered from the surface of Mound C. With the amount of disturbance, it was thought that numerous artifacts might be recovered from the surface around the mound; this was not the case. Numerous attempts were made to surface collect at the mound; however, the only item recovered was the aforementioned ceramic sherd. This seems very strange, and also raises
Figure 95: Shovel test profiles from area West of Mound C.
additional questions with regard to the association of Mound C with the other two mounds. Perhaps, as was suggested as a possibility for Mound A, Mound C was constructed at a much earlier date than was Mound B. Additional research might find that Mound C was constructed along an earlier channel of the Bayou Francois/New River drainage when the channel was closer than where the New River is today. Whatever the case, the prehistoric cultural association at Mound C could not be determined from this research project.

Summary

In summary, the excavations completed at Mound B for this project encountered several cultural strata. The primary occupation at Mound B was in the Smithfield Phase of the early Marksville Period. This association is corroborated not only by the overwhelming majority of early Marksville varieties of ceramic sherds, but also agreeable dates from five of six radiocarbon samples that were tested from proveniences containing early Marksville ceramic sherds (Table 10 and Appendix). Prehistoric cultural materials encountered at Mound B, such as areas of burned bone, charcoal, and charred cane, have also been recovered at other Marksville Period sites. At this point, it is difficult to speculate what role the site played or to what extent the Broussard Mounds site was related to other sites occupied during the early Marksville Period. However, it would not be surprising if future researchers found that this site was actually a key location for the expression and ultimately the spread of Marksville Culture along the New River and into the Maurepas Basin.

Although deeply buried cultural material was excavated from the test units at Mound B, there is no reason to believe that the test units identified the earliest occupation at the mound. The test unit excavations were ended because of time restraints and logistical issues associated with the inundation of water. If further archaeological research is conducted at
Mound B, it should focus on large area excavations to identify the nature of the various lenses that are present around the periphery of the mound and also incorporate a methodology that allows for excavations at greater depth.

Mound A excavations, while identifying the heavily disturbed remains of a late nineteenth century and/or early twentieth century structure at the base of the mound, did not provide the answers to the question of the cultural affiliation of the mound. A few undiagnostic lithic flakes were recovered from the test unit excavations, but without diagnostic tools or ceramics, there is no way to place this material into a cultural framework. Therefore, the chronological relationship of Mound A to the other mounds remains undetermined. However, the relative absence of ceramics and an indication of much older, more closely associated drainages, as observed from LIDAR data, suggests that the antiquity of Mound A may be greater than Mound B. As at Mound B, excavations had to be curtailed due to the logistics associated with the inundation of water in the test units. Any future archaeological research should focus on much deeper excavations than what could be completed for this research, and should also make use of coring devices to get a clearer understanding for the construction of Mound A.

Excavations at Mound C were limited to only five shovel tests. These shovel tests revealed nothing about the cultural occupation at the mound. Only speculations could be made as to the age of this mound. Like Mound A, the absence of pottery at Mound C may suggest an Archaic Period construction. LIDAR data indicates that other drainage channels in closer proximity to the mounds may have existed at an earlier date. Additional research should address this if Mound C is to see further investigation. But more importantly, an effort should be made to prevent further destruction of this mound before nothing remains to
investigate. Effort should be focused initially on recording areas of the mound that have been exposed, then the mound should be stabilized to prevent further erosion of the areas exposed. Of course, an effort has to be made on the part of the landowners to abstain from further destruction of the mound; in dealing with the landowners, archaeologists should stress the potential of the mound to give insight into past lifeways.
CHAPTER 7: CONCLUSIONS

Four types of remote sensing systems were tested at the Broussard Mounds site. On the whole, the application of remote sensing for locating archaeological remains had mixed results. The images that were analyzed and the instruments used were quite varied in terms of techniques used and idiosyncrasies involved with their application. With the exception of the 35mm infrared photography, all of the techniques used required significant computer manipulation. The aerial photography, including historic photography, and the ATLAS data involved visual analysis using magnifying and stereo imaging equipment and computer enhancement. In the case of the ATLAS data, as well as the scanned aerial photography, software specific techniques associated with ERDAS Imagine, ENVI, ArcGIS, and other imaging software were required in order to achieve suitable images for further visual inspection and comparison. The 35mm photography required meticulous notation of image settings and a basic comprehension of how cameras work. Also, locating sources to process the infrared film in a timely fashion was difficult. The ground penetrating radar required an understanding of instrument specific techniques while collecting data in the field, and a considerable amount of software specific knowledge while completing the computer enhanced processing using Radan, Fieldview, GPR Process, Surfer, and finally ERDAS Imagine.

In addition to the instrument specific elements involved with the different techniques used for this project, other field equipment, such as transits and global positioning units, had to be utilized to acquire ground reference locations. A summary of the effectiveness and a discussion of the pitfalls and potential associated with each of the remote sensing techniques
used for this project are offered below, along with suggestions on how this type of research might be carried out more efficiently.

The modern color infrared aerial photography used for this project was unproductive in terms of locating archaeological features at the Broussard Mounds site. Only a few faint suggestions of previous field roads and possible structure locations were observed in the form of soil marks that might suggest a correlation with historic occupation at the site. One possible anomaly was observed southeast of Mound A that might suggest some type of prehistoric earth moving, but this anomaly was inconsistent and not well defined. By and large, the low productivity of the infrared photography was attributed to the unfortunate time window in which the photographs were collected. Recent crop marks related to agricultural activity and significant vegetation patterns related to other industrial work substantially reduced the usefulness of the photos for archaeological applications. Had the film been collected specifically for such applications, a more appropriate time would have been chosen for data collection.

The historic aerial photographs held more potential in terms of archaeological information. Several structures and roads are visible on the early photographs over the site, and some inferences can be made for possible activity areas and functions related to the roads, structures, and other observable patterns related to the historic occupation at the site. Outside of the observable historic elements of the photographs, the older images also provide a better record for prehistoric occupation because of the limited amount of modern disturbance that had occurred at the site at the time the photographs were taken; this was the case with the possible mound identified on the western boundary of the site within a bend in the New River (see Chapter 5). Today, no evidence of a mound exists on the surface in this
location, outside of a few prehistoric ceramics and fired clay, because the area has been
drastically altered by modern machinery. These findings would suggest that archaeologists
should always make use of historic aerial photography, when available, because of the
potential it holds as a record of the area of study at a time when disturbance was much less.

The ATLAS imagery acquired over the Broussard Mounds site was found to have a
little more potential than the color infrared aerial photography for the identification of
archaeological features, at least with regard to the historic occupation. Although not
validated archaeologically, high returns on the thermal bands of the ATLAS data show a
strong correlation with the location of at least one structure from the historic aerial
photographs. Archaeological investigation verified the location of another partially intact
brick structure that was located through the use of GPR, and the thermal bands of the
ATLAS sensor show a high return near this location as well. Given the proximity of this
high return to the observed feature and the unknown extent of the intact areas of the brick
structure, the data suggest that there is an association between the GPR returns and the
thermal bands of the ATLAS sensor. Unfortunately, no anomalies believed to be related to
the prehistoric occupation of the site were observed using the ATLAS data, but this does not
mean ATLAS imagery cannot be used successfully at other sites. A better understanding of
all of the parameters involved with the successful application of these data will prove useful
in future projects that attempt such research. Projects involving ATLAS imagery should
work toward building a signature library for known archaeological features. In the future, the
classification of multispectral and hyperspectral digital imagery, including ATLAS, for
ground cover related to archaeological features will lead to much more efficient research
endeavors.
Black and white infrared and color infrared photographs were taken at various locations at the Broussard Mounds site with the use of a 35mm camera. The infrared photography showed only a few possible features that were located through the visual inspection of these images. A few circular vegetation patterns near Mound B, observed as differential spectral reflectance in the near infrared portion of the spectrum, may indicate some type of prehistoric activity; but these areas were not tested archaeologically and are most likely related to more recent activity at the site. Also, north of Mound A, some areas of differential reflectance were observed. These areas could be associated with historic structures in the area. However, they do not directly correspond to the locations of structures observed on the historic photographs and these locations were not tested sufficiently to allow for a confirmation of what the source of the variation may be.

One area that did show more promise of some type of structure was adjacent to the concrete pad at the summit of Mound A. This anomaly has a boxy appearance and seems to be directly related to either the most recent house that was previously located on this mound, or it may be associated with an older structure. The anomaly was interpreted as being the result of the impact on the vegetation from some type of extension, such as steps or a porch, off the most recent house on the mound. Testing of the anomaly might prove otherwise, but this appears to be the most likely explanation given the location and overall size of the anomaly.

Although the inspection of these photographs yielded little in the way of results, the fact that some variation in reflectance within the near infrared can be observed from the photographs shows that the use of 35mm infrared film has potential for archaeological research. Perhaps using this type of film under more controlled conditions, such as
suspended from differing heights over known archaeological features or using some other method to acquire extremely low altitude vertical images over known features, will give better results.

The ground penetrating radar was the only method that was ground truthed. The GPR also showed the greatest number of anomalies after processing, even though the setup during data collection was not properly adjusted for optimum data acquisition. Results from the use of the GPR were mixed. Anomalies that were tested at Mound B, although possibly correlated with archaeological phenomena, were largely inconclusive. At Mound A, the results were more encouraging. The two anomalies selected for testing were both consistent with what was expected prior to excavation. The brick feature located within the archaeological test units was directly associated with a high return; and, even though nothing was encountered in the shovel tests in the location of the other anomaly, the shovel tests did not yield information to negate the idea that this anomaly was related to a previous or modern field road. At Mound C the findings were quite disappointing. Nothing in terms of cultural remains, other than a few small brick fragments from one shovel test, was recovered. This may indicate that all of the anomalies in this area were in some way the result of natural stratigraphy. Numerous concretions recovered from the shovel tests were most likely responsible for the high returns in this location, but these anomalies could also be the result of other, undetermined stratigraphic inconsistencies.

The archaeological testing at the site, like the remote sensing, also had mixed results. Even though the primary objective of this research was completed through the testing of different remotely sensed data sets, the second objective of identifying the cultural components at Mound A and Mound C was not. Nothing significant in terms of the
identification of prehistoric occupation and/or construction of either of the two mounds was recovered. However, with the exception of the lithics at Mound A, the relative absence of material at these two mounds, and the use of the LIDAR DEM that was surprisingly rich in information, suggest a greater antiquity for these mounds. The realization that Mound A, and perhaps Mound C, might be associated with cultural groups that predate the early Marksville component at Mound B dramatically increases the range of possibilities for interpretations of the site formational process at the Broussard Mounds site.

Excavations at Mound B, on the other hand, were quite fruitful in terms of archaeological data recovery. Not only was the associated Marksville component determined to be associated with the early Marksville Smithfield phase, as opposed to the later Gunboat Landing phase, but the amount of quality material acquired for dating purposes and the recovery of diagnostic Marksville ceramic types is quite significant. In addition, the flotation material, when thoroughly processed, may provide much needed subsistence data for the early Marksville period, or this material may lead to a better understanding of mound construction activities at Marksville sites.

Although, on the whole, this research resulted in only limited success in terms of effectively locating archaeological remains through the application of remote sensing, several key elements have been noted. Archaeologists who wish to make use of remote sensing need to be cognizant of the types of data that are available, and the particulars involved with their use. To contribute insightful information for future researchers interested in pursuing projects similar to this research, a few key points will be offered here.

First, no single type of remote sensing is always effective at locating archaeological features, as can easily be seen from this research. The use of multiple types of data
acquisition will provide a greater possibility for success. The results of this research show that only one of the anomalies encountered had potential for possibly being identified across two data sets; this was the brick feature near Mound A that was excavated. This feature was located using GPR, and may have also been visible on the ATLAS imagery within the short wave and thermal infrared bands. Other anomalies, although not archaeologically tested in most cases, were only visible on a single data set.

One of the most important lessons learned from this research is how important ground control is to the overall project. A geographic coordinate based grid system should always be used; this facilitates greater flexibility in terms of making comparisons among different data sets and overall management of the data. Unfortunately, this type of grid system was not employed at the Broussard Mounds site; thus, the processing and interpretation of data were considerably more difficult because of problems with accurately associating site coordinates based on arbitrary, site-specific elements. Had a universal transverse mercator (UTM) grid system been used site-wide, with all datums, grid nodes, excavations, etc., tied to actual UTM coordinates, then many hours of manipulation would have been saved and the accuracy of the data would have most likely increased.

Finally, if future research using remote sensing is to be advanced in terms of archaeological applications then archaeologists need to become familiar, not only with what is available, but also with how to use what is available. The learning process involved with such an endeavor may be quite difficult, especially when specific software and instruments are being used. However, by applying different technologies and testing their usefulness for varied, but specific, archaeologically oriented objectives, archaeologists can generate advancements in the efficiency of the available techniques in the future.
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APPENDIX:
GRAPHS OF RADIOCARBON PROBABILITIES

Wk11763 : 1990±54BP

- 68.2% probability
- 50BC (68.2%) 80AD
- 95.4% probability
  - 160BC (1.7%) 130BC
  - 120BC (93.7%) 130AD

Calibrated date

Wk11764 : 1902±53BP

- 68.2% probability
- 20AD (53.2%) 140AD
- 150AD (8.0%) 180AD
- 190AD (7.0%) 220AD
- 95.4% probability
  - AD (95.4%) 240AD

Calibrated date
VITA

Benjamin Goodwin was born in Opp, Alabama, and for most of his life, lived at various locations across the southern part of the state. He is the oldest of four sons of Patrick and Barbara Goodwin, who currently live near Red Level, Alabama. He graduated from Red Level High School in 1991 and earned an Associate of Arts degree in 1993 from Lurleen B. Wallace Junior College in Andalusia, Alabama. In 1996 he graduated Cum Laude with a Bachelor of Arts degree in social science from Troy State University in Troy, Alabama. While at Troy State University, he was employed with the Troy State University Archaeological Research Center as an archaeological field and laboratory technician and was later given responsibilities as a project supervisor for projects during all phases of cultural resource management investigations. Between 1993 and 1997, he was also employed as an archaeological field technician on short term projects for the Alabama Historical Commission in Montgomery, Alabama, and Pensacola Archaeological Laboratories in Pensacola, Florida.

In 1997, he moved to Baton Rouge, Louisiana, to work as an archaeological field and laboratory technician with Surveys Unlimited Research Associates (SURA). During the summer of 1998 while still employed with SURA, he also worked on projects as a field technician with Earth Search, Inc., in New Orleans, Louisiana. He was employed by the Louisiana State University Museum of Natural Science as assistant to the Regional Archaeologist for Southeast Louisiana in 1999. One year later, he was awarded a fellowship from the National Aeronautics and Space Administration Graduate Student Researchers Program for research in the pursuit of a Master of Arts degree in anthropology from the Department of Geography and Anthropology at Louisiana State University.
In March 2002, he was employed as a Research Scientist with Lockheed Martin Space Operations in the Geophysical and Archaeological Technologies and Environmental Remote Sensing Laboratory at Stennis Space Center, Mississippi. Presently, he remains employed with Lockheed Martin and will graduate from Louisiana State University in August of 2003 after completing the requirements for a Master of Arts degree in anthropology in the Department of Geography and Anthropology.