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Archaeological Prospecting Using Historic Aerial Imagery: Investigations in Northeast and Southwest Arkansas

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ARCHAEOLOGICAL PROSPECTING USING HISTORIC AERIAL IMAGERY: INVESTIGATIONS IN NORTHEAST AND SOUTHWEST ARKANSAS

ARCHAEOLOGICAL PROSPECTING USING HISTORIC AERIAL IMAGERY: INVESTIGATIONS IN NORTHEAST AND SOUTHWEST ARKANSAS

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Arts in Anthropology

By

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ABSTRACT

This research investigates the potential of historic aerial photographs as a tool for archaeological site prospecting. Craighead and Mississippi Counties in northeast Arkansas and areas adjacent to the Red and Little Rivers in southwest Arkansas were chosen as study areas. These regions have undergone significant changes in the past few decades and were expected to yield visible types of archaeological sites. Historic aerial images of these areas were obtained through the U.S. Geological Survey's EarthExplorer database (http://earthexplorer.usgs.gov/). These images were processed using Agisoft PhotoScan Professional to produce extensive regional orthoimages.

Using the Arkansas Archeological Survey's Automated Management of Archeological Site Data in Arkansas (AMASDA) database, known archaeological sites dating later than Late Woodland were compared against PhotoScan-generated orthoimagery to see if they were visible using a tripartite classification scheme: site invisible, site possibly visible, and site visible. Trends in site visibility were assessed in terms of the photographs' characteristics (e.g., dates, geographic scales, download resolutions) and the nature of the archaeological sites (e.g., surface scatters, mound sites, middens, standing structures).

For specific archaeological sites, possible archaeological, modern, and natural features were digitized. Within-site visibility was reexamined with respect to the sites' temporal ranges, previously documented structures and features, seasonal differences of the imagery, and disturbances from modern land-use. Historic digital elevation models (DEMs) were generated in PhotoScan to assess the performance of the software's geometry-building algorithm for intrasite prospecting.

Overall, only a small percentage of specific site types (i.e., mounds, historic structures, middens) were classified as definitively visible. However, the site classification scheme used in this study provides a subset of sites with potential archaeological anomalies, which can be investigated more closely with site survey reports. High-resolution orthoimages and DEMs produced from stereopairs in PhotoScan also present archaeologically promising anomalies for subsequent analyses.

This thesis is approved for recommendation
to the Graduate Council

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I. INTRODUCTION

Since O. G. S. Crawford's pioneering studies (1923; 1924b; 1924a), aerial survey has become a critical method of archaeological prospecting in many parts of the world, and some have claimed that it historically has been the most productive means of site discovery (Wilson 2000; Braasch 2002:19). Aerial methods provide wide coverage in comparison to traditional shovel-tests, pedestrian surveys, and geophysical investigations, offering far greater area for cultural landscape features and archaeological sites to be detected and mapped. Furthermore, repeated aerial surveys provide historical imagery that documents temporal changes in site visibility and preservation. Despite the potential utility of aerial image analysis as a means for finding archaeological sites and for intrasite investigation, the technique has seen rather limited application in the United States (Kvamme 2005:447; Vogel 2005:222; Dore and Wandsnider 2006:28).

This study was in part motivated by a 2006 Arkansas Digital Orthophotography Program (ADOP) image of the Old Town Ridge Site (3CG41) presented in *Southeastern Archaeology* (Lockhart et al. 2011:56). In this image, the outline of a Middle Mississippian enclosure is clearly visible alongside a relict paleochannel. This prompted questions about whether other sites would be visible using historic imagery and under what environmental, seasonal, or land-use circumstances. This research assesses available aerial photographs from the U.S. Geological Survey (USGS) EarthExplorer database, temporal and environmental conditions of available photographs, and archaeological site types to determine whether certain combinations of factors enhance or detract from site visibility.

A. AERIAL PROSPECTING: METHOD AND THEORY

Wilson's *Air Photo Interpretation for Archaeologists* (2000) is a seminal reference for aerial image interpretation, presenting basic principles that apply to all forms of aerial photography. Originally published in 1982, this work summarizes key historical developments in European aerial archaeology, and it discusses how natural and anthropomorphic processes produce physical contrasts on the landscape that can be used to identify archaeological sites on aerial photographs. Wilson notes that archaeological remains are typically recognized as surface patterns composed of differential shadowing, snow and frost melting, standing water, crop growth (cropmarks), and soils (soil marks). Focusing on the latter two phenomena, Wilson utilizes British case studies as an aerial index of archaeological site types (e.g., henges, barrows , round-ditches, hillforts) and natural "non-archaeological features" (e.g., jointing in bedrock, frost-mounds, cultivation patterning, irrigation-marks) with deceptively similar morphologies. Wilson also specifies environmental and temporal conditions that are amenable to archaeological feature visibility in Britain.

Riley (1987) provides a similar overview of differential soil color (soil marks), shading, snow melting (snow marks), plant growth (vegetation marks), water pooling, and soil dampness (damp marks) as potential indicators for archaeological features. Furthermore, he discusses stages for planning custom flying missions, alternatives to airplanes (i.e. kites, model airplanes, balloons), camera and film specifications, the logistics of capturing photos, image rectification and mapping, and strategies for interpreting the final images. In particular, he notes that systematic classifications of site types can be formulated using the following characteristics: color, shape, size, pattern, texture, and shadows (Riley 1987:60–61). Using case studies to demonstrate this approach, Riley's work highlights the importance of gaining familiarity with the local environmental, archaeological, and modern cultural contexts being investigated.

Rączkowski (2002) situates ideas behind aerial methods and interpretation within larger theoretical trends in archaeology, particularly processual versus post-processual archaeology. He refers to aerial archaeology as fitting within the processualist "paleontological concept of the archaeological record" in which aerial images were acknowledged as objective evidence to corroborate other forms of archaeological data (Rączkowski 2002:317–318). From this perspective, aerial images were viewed as a medium for "pure perception" and measurement reflecting observable differences in soil properties, topography, and crop growth. In turn, aerial archaeology was incorporated into the interpretive toolkits of scholars investigating cultural ecology. For example, *Aerial Photography in Anthropological Field Research* (1974) is a compilation of applied aerial archaeology investigations worldwide—primarily in Mexico—and how they pertain to broader categories of cultural ecology, ethnography, and anthropology.

Rączkowski (2002) claims that post-processualist perspectives, on the other hand, encourage a view of "aerial photographs as text." In particular, the narratives associated with oblique and vertical aerial images consist of multiple stages that each have subjective biases: image collection (for oblique images), image selection for analysis, mapping archaeological features, presentation of data and interpretations, and the audience's perception of those presentations (Rączkowski 2002:320–323). The use of aerial images is also biased by the researcher's objectives for interpretation, familiarity with the region of analysis, and confidence in the level of abstraction that can be gleaned from such resources. Following Rączkowski's argument, these critiques should not undermine past aerial interpretations, but rather foster a more nuanced contextualization and understanding of them as narratives.

B. DEVELOPMENTS IN AERIAL ARCHAEOLOGY

The regional scope and accuracy of aerial photographs have proven advantageous for archaeological prospecting and mapping applications worldwide. Deuel's *Flights into Yesterday* (1969) provides an overview of early stages of aerial archaeology during and after WWI. He highlights aerial surveys of the Near East by the German army under the direction of Wiegand, as well as Beazeley's pioneering efforts over Mesopotamia (Deuel 1969:17–19). Following the war, O. G. S. Crawford and the British Royal Air Force set aerial archaeology in motion in Europe through publications pertaining to lynchet systems in Wiltshire and the "Stonehenge Avenue," later culminating in a collaborative project between Crawford and Keiller to survey archaeological sites in Wessex (Deuel 1969:26, 32–33, 36–37). In turn, *Wessex from the Air* (Crawford and Keiller 1928) set the precedent for developing techniques of aerial archaeology in Britain and elsewhere.

Aerial explorations continued worldwide and were highly successful in Europe (e.g., Scollar 1965; St. Joseph 1945; St. Joseph and Coombe 1977; Bradford and Williams-Hunt 1946; Agache 1962), the Middle East (e.g., Poidebard 1934), North Africa (e.g., Baradez 1949), Central and South America (e.g., Ricketson and Kidder 1930; Shippee 1932; Johnson and Platt 1930; Reiche 1949), and the American Southwest (e.g., Judd 1930). Today, aerial archaeology is still practiced around the world through organized aerial reconnaissance and archival programs. A few examples include the English Heritage aerial collection and National Mapping Programme in England (Winton and Horne 2010), Aerofototeca Archeologica in Italy (Deuel 1969:286), the Royal Jordanian Air Force surveys in the Middle East (Kennedy 2002), the Archaeological Aerial Photography Programme in Slovenia (Gojda 2002), and the Institute of Archaeology's program based in Prague (Gojda 2002).

Recent studies (Verhoeven et al. 2009) have focused on the use of unmanned aerial vehicles (UAVs) and man-operated apparatuses—helikites, model airplanes, powered parachutes—to obtain high-resolution custom aerial and multispectral imagery. These methods are becoming increasingly cost-effective and precise in documenting archaeological sites. However, as newly emerging techniques, they unfortunately are limited in terms of their temporal scope.

C. AERIAL ARCHAEOLOGY IN THE U.S. AND ARKANSAS

Although aerial archaeology has been successfully applied for archaeological prospecting programs elsewhere, utilization of historic aerial images in the United States has been largely restricted to occasional mapping and visualization applications. This can be attributed to fundamental differences in regional archaeology, environment, and land use. For example, visible site types, soil conditions, and agricultural patterns have allowed thousands of sites to be detected primarily in the form of differential crop growth (Wilson 2000), whereas in the United States such conditions generally do not predominate. However, some regions such as the American Southwest have proven amenable to aerial prospecting. Furthermore, Rączkowski (2002:315–316) argues that the processual movement in United States archaeology encouraged more rigorous analysis of aerial photographs through image processing and for use in predictive modeling. Although not exhaustive, a brief overview of applications of aerial archaeology in the United States is provided to demonstrate the current status of aerial prospecting. Examples from Arkansas are also presented to contextualize the present study.

1. United States

McKinley and Wells photographed Cahokia Mounds from the air in the early 1920s (Bushnell Jr. 1922). However, the Lindberghs' flights over the Four Corners region of the United States in 1929 (Kidder 1930) represented the first landmark example of extensive aerial prospecting in the United States archaeology, and these explorations had considerable success in locating both known and unknown ruins. In 1930, an aerial survey commissioned by Judd effectively mapped prehistoric irrigation canals along the Gila and Salt River Valleys in Arizona, which were not traceable on the ground surface (Judd 1930). Furthermore, Palmer serendipitously discovered geoglyphs of the Lower Colorado River near Blythe, California, in 1932 (Deuel 1969:248). Although site visibility was particularly good in the Southwest, other discoveries were occurring in the eastern United States during this time. Drawing largely from his own aerial surveys of Ohio earthworks, Reeves' "Aerial Photography and Archaeology" (1936) promotes aerial photography as an efficient means of mapping, recording, and exploring known archaeological sites. As another notable example, an aerial survey of Poverty Point commissioned by the Mississippi River Commission revealed prominent octagonal ridges, which previously had not been detected from the ground (Ford 1954).

The most extensive work in aerial image analysis in the United States thus far has been in the American Southwest, which has had a series of successful applications using panchromatic and multispectral imagery since the 1970s. This research began with the Chaco Project—a joint venture between the University of New Mexico (UNM) and National Park Service (NPS)—that brought together many specialists and advocated for remote sensing. For instance, Gumerman and Lyons (1971) compared different film types (panchromatic, infrared, radar, etc.) and their advantages and disadvantages for remote sensing applications for sample sites in the Southwest.

Furthermore, Drager and Lyons (1985) utilized a traditional stereoplotter to very accurately draw topographic contours of both local areas and monumental architecture for the Chaco Mapping Project. Thermal Infrared Multispectral Scanner (TIMS) data also have been used to effectively trace prehistoric roadways in Chaco Canyon (Sever and Wagner 1991).

Despite these early successes, aerial research programs did not materialize in United States archaeology as they did in Britain. Rather, aerial archaeology consists of occasional and isolated attempts to investigate relatively small regions, usually on a site-by-site basis. Aerial images are more commonly utilized as a backdrop for presentation rather than an object of analysis. A few noteworthy exceptions exist. For instance, Southern Illinois University launched a series of aerial surveys in 1964 that produced regional coverage intended as a guide for field reconnaissance, as well as site-specific images to aid in the placement and recording of excavations (Porter 1965). Likewise, the Vandenberg Air Force Base's Applied Earthworks program in California conducts regular aerial surveys for cultural resource management purposes, particularly to monitor site disturbance and other environmental changes through time (Dore and Wandsnider 2006:75–77). However, emphasis on state-based archaeological protocols in the United States generally hinders attempts to organize and fund unified aerial archaeological programs as occur in Europe (Kvamme 2005, 447; Deuel 1969:221).

2. Arkansas

Clyde Dollar's "Aerial Archeology: In Search of a Pilot Site for Arkansas" (1962) specifically advocates for the use of aerial prospecting in Arkansas. He provides an overview of the successful application of aerial survey for site prospecting in the Rhineland and factors that contribute to site visibility. In doing so, he encourages Arkansas readers to be alert for these kinds of archaeological sites: “What must be located first is a ‘pilot site’ so that it will be possible to tell the approximate time of year that other sites of a similar nature will be visible” (Dollar 1962:7).

Hoffman’s 1968 survey of the Ozark Reservoir in Franklin County, Arkansas, represents an early pioneering attempt conduct an aerial survey for archaeological sites. Included as part of the Ozark Reservoir Papers (Hoffman et al. 1977), Printup's chapter is one of the few explicit efforts to discuss optimal conditions for aerial survey in Arkansas. During two aerial surveys of the Ozark Reservoir from late May to early June 1968, Printup took oblique panchromatic and near-infrared (NIR) photographs of previously recorded archaeological sites. Using the Spinach Patch (3FR1), Natural Levee (3FR33), and River Bank (3FR23) sites as examples, he indicates that moist ground conditions and the use of NIR film provided the most useful indications of potential archaeological features (Hoffman et al. 1977:72–73).

For example, potential features appeared well in the aerial images of the Natural Levee site, which could be attributed to differential drainage and resultant color differences of the light-colored sandy soils (Hoffman et al. 1977:79). Similarly, the visibility of the East Mound, West Mound, and Plaza Area of Spinach Patch was attributed to lighter-colored sediment in contrast to the darker soils of the organic-rich midden (Hoffman et al. 1977:83–84). Of these features, the West Mound was the easiest to differentiate on black-and-white imagery due to differences in soil color, elevation, and organic content. The River Bank site also exhibited a dark midden stain rich in organic materials that may have “increase[d] the cohesiveness and reduce[d] the porosity, increasing the moisture retention rate in that area” (Hoffman et al. 1977:120–121).

D. INTERPRETIVE POTENTIAL OF HISTORIC AERIAL IMAGERY

In contrast to contemporary aerial surveys, archived aerial images provide a unique resource for interpreting past cultural landscapes, especially in areas that have undergone significant natural and cultural transformations. Historic photographs can pinpoint archaeological features and structures—some of which are undetectable from the ground or have been destroyed—with remarkable clarity. Furthermore, the temporal ranges afforded by historic aerial images allow for archaeological sites to be monitored through time. Cowley et al. (2010, 2) note that landscape dynamics can be interpreted from aerial photographs examined as a series, helping to move archaeologists away from "period-specific approach[es] to the past." Although aerial surveys were conducted worldwide in World War I and were quite extensive during and after World War II, photographs archived at the National Archives and Records Administration (NARA) and The Aerial Reconnaissance Archives (TARA) remain "frequently little known, sometimes inaccessible, and consequently under-utilized" (Cowley et al. 2010a:1).

As demonstrated by case studies presented in recent volumes, historical aerial images—particularly those dating to the WWI and WWII eras—have been successfully utilized for archaeological purposes on an international scale. For instance, *Aerial Archaeology: Developing Future Practice* (Bewley and Rączkowski 2002) presents numerous applications of aerial archaeology combined with other methods, overviews of formal aerial survey programs, and the statuses of aerial imagery databases in the Near East and Middle East, Europe, and Russia. Likewise, Cowley, Standring, and Abicht's (2010b) compilation presents a wide spectrum of global examples pertaining to the use of historic aerial images for (1) archaeological mapping, (2) documenting social, political, and environmental change, (3) managing cultural heritage, and (4) investigating wartime history and archaeology.

Aerial images can predate significant land modifications that obscure archaeological anomalies. Furthermore, geometric relationships between overlapping aerial images can be used to construct historic digital elevation models (DEMs), three-dimensional (3D) representations of surface topography. For this reason, declassified satellite imagery from the CORONA mission has proven highly effective in archaeological site prospecting. Casana and Cothren (2008) and Casana, Cothren, and Kalayci (2012) offer methodological overviews and summarize recent discoveries. The CORONA Atlas of the Middle East (http://corona.cast.uark.edu/) provides an index of known sites and multiple layers of orthorectified CORONA images, dating from 1967 to 1972. This allows not only for historical modification of archaeological sites to be monitored, but also for new sites to be discovered that have been destroyed through decades of land-use practices (e.g., land-leveling, agricultural expansion, urban development, dam construction). Furthermore, many sites can be dated on the basis of their morphologies on the imagery, providing a quick means of site classification. Stereo analysis and DEM extraction of CORONA images also have proven an inexpensive and fast means of visualizing past landscapes. Although site visibility relies on the nature of the archaeological remains, the trajectory of land use, and a variety of environmental parameters, the successful use of historical imagery suggests that similar site indices can be developed on a regional scale for places with sufficient aerial coverage.

In the United States, custom aerial imagery is limited to archival photographs or commissioned flights over specified areas, which can cost hundreds to thousands of dollars depending upon the size of the study region (Hailey 2005:71). Systematic surveys were commissioned by the United States Department of Agriculture (USDA) from WWII and onward, which are housed at the National Archives in College Park, Maryland. At this time, archived film at the National Archives can either be photographed by a researcher on-site or purchased from licensed venders who are permitted to scan them directly. Provided that a researcher can be sent to the National Archives to photograph the aerial film with a high-resolution camera, the cost of such a venture would not be expensive, particularly when considering the number of aerials that could be photographed. A compilation of free, downloadable historic aerial imagery is also available for certain areas through EarthExplorer, an internet archive of geographic data provided by the U.S. Geological Survey (USGS). The EarthExplorer holdings were utilized for this study to assess its potential for archaeological prospecting.

Generally speaking, historic and contemporary aerial images are usually acquired from extant archives and satellite data to give quick overviews of archaeological sites, to plan surveys (e.g., geophysical surveys), and to compare with other data. Burks' (2010) investigation of Hopewell and Adena earthworks in Ohio is a promising case study that uses archived aerial imagery to map and remap archaeological sites. Specifically, he integrates Ohio State Preservation Office site files, historic maps, USDA aerial photographs, modern geographic data (e.g., Laser Imaging Detection and Ranging or LiDAR), and geophysics into a geographic information system (GIS) to reexamine these earthworks. Although such archival materials are oftentimes difficult to access and interpret, he argues that combined archival, geophysical, and other geographical data could vastly improve current archaeological site databases, particularly with regard to intrasite analysis (Burks 2010). Overall, the successful use of aerial images in conjunction with other forms of evidence in areas of intensive agriculture could suggest that aerial site prospecting in Arkansas could be potentially viable.

Likewise, Vogel (2005:3–4) utilized aerial images from the National Archives in College Park, Maryland, as part of his examination of mound locations with respect to viewsheds and alluvial bottomland in the “Northern Caddo Area,” focusing on northwest Arkansas and eastern Oklahoma, extending slightly into southeast Kansas and southwest Missouri. Descriptions and aerial images acquired for his study are provided as an appendix to his dissertation. He also includes copies of the images in TIFF and GEOTIFF format, but the relatively poor quality of scans used for analysis reduced the utility of the images for interpretation. Vogel (2005:224–225) notes that many of the mound sites are difficult to identify without prior knowledge of their specific locations. As such, he does not use the aerial images as a site prospecting tool, but rather as evidence for intrasite analysis.

Such studies represent localized, but important, strides in justifying the use of aerial photographs as a mapping and prospecting tool in the United States. However, a systematic means of utilizing aerial images for regional and intrasite prospecting has not yet formalized. This study will present a methodological guide for photogrammetrically processing and interpreting these media for archaeological prospecting.

II. DATA AND METHODS

This section describes research objectives, the study areas, initial assumptions for aerial prospecting, variables considered, and the nature of the data utilized. Furthermore, it details procedures for creating extensive regional orthoimagery, assessing site visibility, and conducting intrasite analysis. PhotoScan was chosen for this analysis because it can process tens to hundreds of photographs accurately with minimal input on the part of the user.

A. RESEARCH QUESTIONS

As stated previously, the effectiveness of aerial imagery as a method of site prospecting has not been addressed systematically in the United States. This study will attempt to identify aerial image and archaeological site characteristics amenable to visibility. Furthermore, photogrammetric processing of historical images has been underutilized as an archaeological prospecting tool in the United States. If key factors can be identified that contribute to or detract from site visibility in these data, then this information could drastically improve the outlook for aerial image analysis as a new means for site prospecting. Put simply, this study will address the following research questions:

1) Can historical aerial images be successfully utilized for site prospecting on a regional scale in Arkansas? If so, what kinds of imagery and site types are amenable to aerial prospecting?
2) At the intrasite level, can PhotoScan-generated orthoimages and DEMs reveal previously known and unknown features and structures?

For the first question, a preliminary visibility assessment was conducted utilizing basic interpretive principles of aerial image analysis and assumptions about detectable features and structures (e.g., mounds, field systems, structural foundations, activity areas). Differences in site visibility were assessed in terms of the photographs' characteristics, including the download quality, geographic scale, and photograph dates. Visible site types were assessed in comparison to the known archaeological sites using metadata from the Arkansas Archaeological Survey's Automated Management of Archeological Site Data in Arkansas (AMASDA) database.

For the second question, intrasite features and structures were sought in the immediate vicinity of selected visible archaeological sites. Case studies present and discuss anomalies in the orthoimages and DEMs, some of which correspond with known features. Environmental settings (e.g., topography, geomorphology), site characteristics (e.g., length of occupation, expected features), and past land use (e.g., plowing, construction) were also taken into consideration.

The performance of the photogrammetric techniques employed is also discussed in terms of the quality of the orthoimages and DEMs, the time and labor commitment involved, and the promise of the method as a whole for site prospecting in cultural resource management (CRM) applications and in academic research.

B. STUDY AREAS

Site visibility was assessed within Craighead and Mississippi Counties, as well as sites along the Red River and Little River in southwest Arkansas (Figure 1). Craighead County was chosen as a starting point to look for visible sites similar to the Old Town Ridge site (3CG41), which has been row-cropped for a long time. Craighead County also has 25 recorded mound sites including Bay Mounds (3CG29), as well as several historic cemeteries. Mississippi County, on the Mississippi Alluvial Plain, was a logical extension of that investigation given the predominance of land-leveled agricultural fields, as well as the presence of major archaeological sites such as the Middle Nodena (3MS3), Upper Nodena (3MS4), Blytheville/Chickasawba Mound (3MS5/12), Sherman Mound (3MS16), Zebree Homestead (3MS20), and Eaker (3MS105) sites.

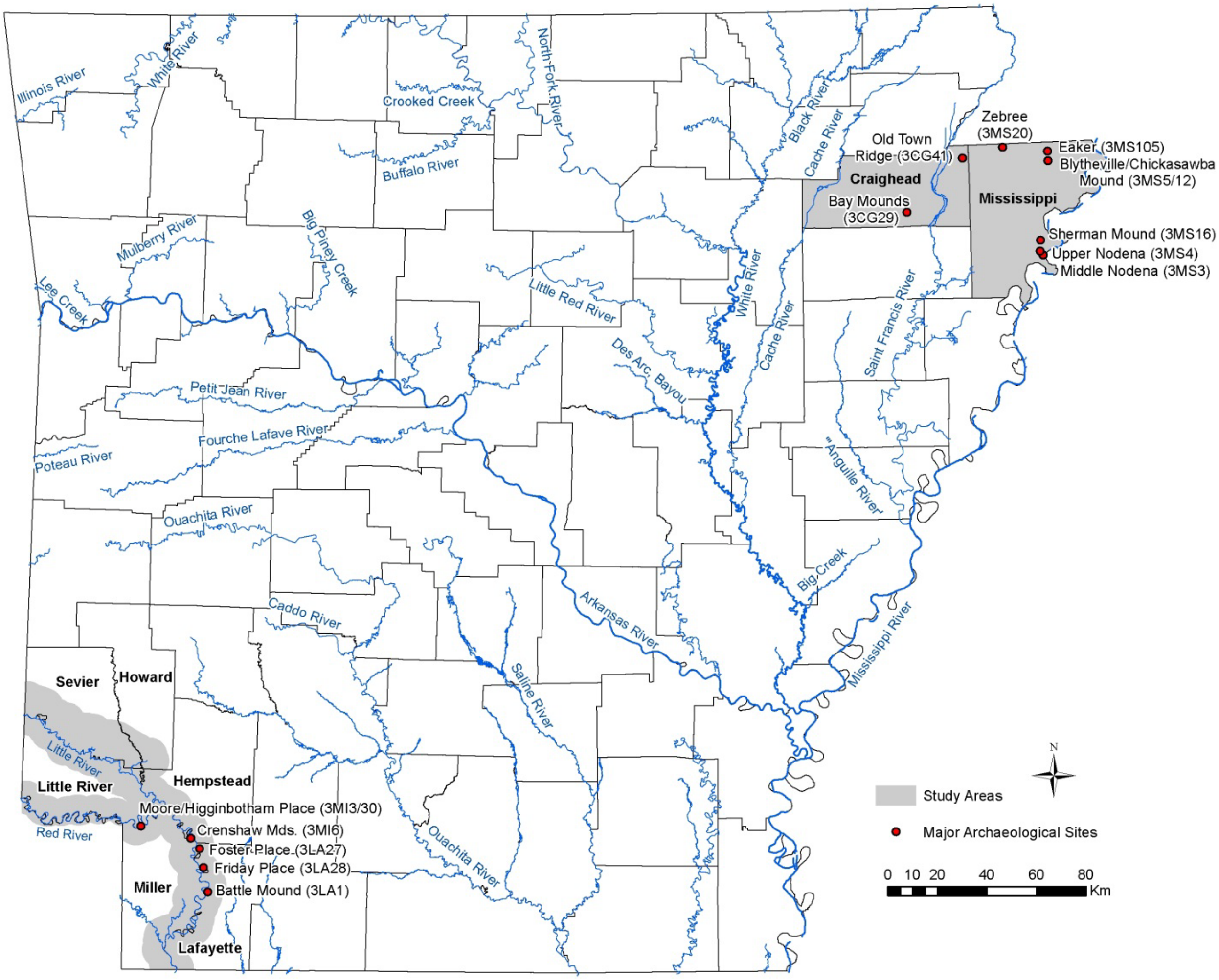


Figure 1 Map of study areas: (1) Mississippi and Craighead Counties in northeast Arkansas and (2) sites near the Red and Little Rivers in southwest Arkansas

Overall, these counties have undergone significant landscape changes historically and in recent times. For example, Scholtz (1968:2) states that "At the time of White settlement nearly all of this region [the Mississippi Alluvial Plain] was forested, and as late as 30 years ago [from 1968] almost two-thirds of the area was still wooded." Although forested areas would be difficult to interpret archaeologically, sites in this region are anticipated to have good site visibility in the early stages of land clearing, making them amenable to historic aerial image prospecting.

After consulting county agents and records from the Soil Conservation Service and Agricultural Stabilization Service in Little Rock, Scholtz (1968; Table 1) provides estimates the acreage cleared in the early 1960s, as well as the acreage of land that was leveled and had the potential to be leveled as of June 30, 1968. Largely supported by federal cost-sharing, deforestation and land-leveling for agriculture and irrigation intensified in eastern Arkansas from the 1950s and 1960s onward, destroying many archaeological sites (Scholtz 1968; McGimsey III and Davis 1968). Archaeological sites in areas of intensive rice farming and irrigation were particularly at risk (McGimsey III and Davis 1968:30).

Table 1 Land-leveling data for Craighead and Mississippi counties in the 1960s (excerpt from Sholtz 1968)

	Estimated Acres Cleared from 1960-1964	Leveled Acreage as of June 30, 1966	SCS Estimate of Acreage Available for Leveling as of June 30, 1966	Percent Acreage Consumed with for Potential for Leveling as of June 30, 1966
Craighead	11,000	13,240	32,000	29.3%
Mississippi	3,000	68,604	98,000	41.2%

The Red River and Little River areas in southwest Arkansas were added to the study region because several key Caddo mound sites are located along these rivers such as Battle Mound (3LA1), Egypt Mound (3LA23), Foster Place (3LA27), Friday Place (3LA28), Crenshaw Mounds (3MI6), and Moore/Higginbotham Place (3MI3/30). The highly mobile Red River has differentially eroded and buried archaeological sites, poorly preserving sites within the active modern channel (<200 BP) (Guccione et al. 1995). However, beyond this area, large mound sites are expected to have high surface visibility in historical aerial imagery, particularly as forested areas were progressively cleared for agriculture.

Again, Scholtz (1968; Table 2) presents the results of a leveling survey conducted for 1960-1964, including the following counties from the Red River and Little River area: Hempstead, Howard, Lafayette, Little River, Miller, and Sevier.

Table 2 Land-leveling data for southwest Arkansas counties in the 1960s (excerpt from Sholtz 1968)

	Estimated Acres Cleared from 1960-1964	Leveled Acreage as of June 30, 1966	Estimated Acreage Available for Leveling as of June 30, 1966	Percent Acreage Consumed with for Potential for Leveling as of June 30, 1966
Hempstead	15,000	404	3100	11.5%
Howard	600	4	1160	0.3%
Lafayette	5,650	5111	4778	51.7%
Little River	13,500	594	3500	14.5%
Miller	23,300	998	6000	14.3%
Sevier	7,100	-	-	-

Another important factor for the inclusion of the Red River area was the availability of free, high-resolution image downloads for the winter months of 1948 and 1949 (Appendix A). Due to time constraints, analysis was restricted to sites adjacent to the Red River and Little River rather than by county boundaries.

C. STARTING ASSUMPTIONS

The remains of archaeological sites often present regular, recognizable disturbances in the ground that are manifested as contrasts in reflectance in aerial images (Wilson 2000). Archaeological sites within the study areas were evaluated under the following assumptions:

1) *Human use of the land displaces soil and modifies soil properties, leading to differences in coloration and vegetation growth.* For example, the construction of built environments, subsistence practices, and territorial markers represent continual manipulation of the land surface that sometimes can be recognized in aerial photographs. Furthermore, middens and anthropogenic soils from prolonged human activity also can appear as darker, organic-rich soils that have different coloration and drainage properties than their surroundings.
2) *Humans generally build structures and transform the landscape within a predictable range of geometric shapes, providing recognizable types for analysis.* Although certain phenomena in nature also create geometric landscape patterning (e.g., prairie mounds, jointing of bedrock), these can be distinguished from cultural anomalies on the basis of size, density and arrangement, and association with known natural and cultural features.
3) *Middens and activity areas can have geometric shapes depending upon the nature of the deposit, but generally they are expected to have amorphous and diffuse boundaries composed of soils with different coloration or drainage.* Sites with middens are codified in the AMASDA site data, and this was taken into consideration when assessing site visibility.
4) *Sites from the Late Woodland and onward are more likely to be visible because of shifts in settlement structure. Earlier sites are expected to be more ephemeral and were excluded from analysis.* For instance, in the Red River region, the Fourche Maline period marks an important transition towards sedentary agricultural subsistence and early mound construction, followed by the development of mound centers and settlements of dispersed

farmsteads during the Caddoan period (McKinnon 2008:13–16). Cultural affiliations used in the AMASDA query are provided in Appendix C.

5) *Artifact scatters, which comprise most of the archaeological sites in Arkansas, are not expected to be visible from the air, but they could be indicative of visible structures or anthropogenic soils.* Therefore, they were included in the AMASDA site query. Single-artifact sites were excluded.

D. CONSIDERATION OF VARIABLES

The quality of aerial imagery is highly dependent on the climate (soil moisture, snow accumulation), time of day, season, and vegetation cover (Giardino and Haley 2006:57–60). Therefore, consideration of seasonality and local weather conditions are of critical importance in aerial photograph interpretation. Differences in soil characteristics caused by anthropological disturbances are exaggerated during certain growing seasons both in terms of regular land cultivation practices (i.e. plowing, irrigation), as well as general plant growth. Individual plants can be viewed as living sensors that indicate the quality of nutrients in the soil. If the soil has been disturbed by some sort of anthropogenic activity, the soil composition will be physically and chemically different from the surrounding soils. In turn, the soil will retain water and grow crops differently, and certain kinds of crops have more noticeable contrasts in growth in response to these factors. For example, Riley (1979:29–30) claims that corn and grasses generally do not work well for aerial prospecting, except that the latter type works well in draught scenarios. Cereal crops with deep roots—barley, wheat, oats, rye—are generally the most responsive with cropmarks becoming apparent early in the crop-growing season through differential germination, and with draught causing exaggerated differences in vegetation height and coloration later in the growing season (Riley 1987:29–31).

Color, shape, size, pattern, texture, and shadows provide a basis for the identification and qualitative comparison of anomalies (Riley 1987:60–61). Keifer (1983:515) presents a similar list for photographic interpretation in general, but uses “tone” instead of color, and he adds another category for “site,” describing the locations of objects in relation to their surroundings. This study primarily will utilize black and white single frames from EarthExplorer, but also will use true-color orthoimages from GeoStor for comparison. Particularly for the former, differences in color are difficult to explain because it can be caused by variations in water retention, soil color, snow melting, vegetation, and/or shading. This study will occasionally posit possible causes for differences in coloration, but will focus primarily on the use of color and tonal contrast for prospecting.

The shape and size of certain anomalies is also important for hypothesizing what certain anomalies represent. Mounds vary in size, but are generally circular, elliptical, or rectangular (Jeter 1990). Pattern or association involves the examination of how anomalies are placed in relation to known features and other anomalies. In turn, this can help the observer determine whether certain contrasts are associated with a particular archaeological context, or whether they are more likely attributed to modern land use or local geomorphology. For example, mounds are commonly found in groups, oriented with respect to open plazas. Some mounds were associated with nearby villages, whereas others hosted peripheral residential structures for individuals engaging in ceremonial practice (Vogel 2005:1). Geophysical surveys adjacent to ceremonial Caddoan mounds (e.g., McKinnon 2008; Samuelsen 2009) further support the presence of auxiliary structures, which have a predictable range of geometric shapes and dimensions.

Texture and shadowing both give an initial impression of an object's geometry. In general, modern features tend to have crisply-delineated edges with exaggerated shading (e.g., shadows from houses), whereas archaeological anomalies are expected to be more ambiguously defined and with more subtle shading for anomalies with topographic relief. However, for larger archaeological anomalies such as tall mounds, shadowing is expected to be more exaggerated.

E. AMASDA

Archaeological site data for Craighead County, Mississippi County, and areas adjacent to the Red and Little Rivers were obtained from the Arkansas Archaeological Survey's Automated Management of Archeological Site Data in Arkansas (AMASDA) database. AMASDA is computer database of all reported prehistoric and historic cultural sites in Arkansas, as well as cultural, geographic, physiographic variables (e.g., UTM coordinates, presence of surface scatters, degree of site disturbance, topographic landforms). AMASDA includes an online graphical interface for federal projects and academic researchers to view mapped sites, query for specific site attributes, and compare the site locations with background geographic data. Furthermore, AMASDA includes digital copies of the accompanying site survey forms, as well as supplemental data and references to published works. Many archaeological sites included in the database were found and reported through federal projects, as required by law. Therefore, the data have some location biases (i.e., most are located next to roads, streams, reservoirs), which should be taken into consideration when assessing the representativeness of the sites examined.

For this study, sites were queried based on the following criteria: (1) sites dating to Late Woodland and later; (2) sites with good location reliability, meaning that the recorded coordinates are deemed sufficient for relocation on the ground (Hilliard and Riggs 1986:6); (3) sites with good cultural affiliation, meaning that these assignments are deemed reliable (Hilliard and Riggs 1986:8); (4) sites where more than one artifact was found (Appendix C). The site files for Mississippi and Craighead counties were obtained in July 2012, and the Red River counties were obtained in October 2012.

F. USGS HISTORIC AERIAL PHOTOGRAPHS

Historic aerial images are readily accessible via the USGS's EarthExplorer online archive of geospatial data (http://earthexplorer.usgs.gov/). EarthExplorer provides a graphical user interface for viewing various cartographic layers, as well as a means downloading layers and their associated metadata. To download these data, the researcher simply defines his geographic area of interest, the range of dates for the imagery, the data type, and the desired scale of the images. This study utilizes the Aerial Photo Single Frames dataset, which consists of panchromatic, color, and infrared film. These were selected instead of the Aerial Photo Mosaics because the scale of the latter was deemed too poor for archaeological prospecting. Most of the aerials processed and analyzed in this study have geographic scales larger than 1:35,000. However, smaller-scale Single Frames were also downloaded to assess their potential for archaeological prospecting. A wide range of other data layers (e.g., Landsat imagery, SRTM and ASTER digital elevation models, National Land Cover data) are available for download for specific regions, but were not utilized in this application.

An added benefit of EarthExplorer is that one can view both the "footprint" of the image coverage and a low-resolution preview for reference prior to downloading. Furthermore, each aerial image has a unique URL containing its associated metadata (Appendix B), and up to 1,000 entries can be downloaded at a time as an ESRI shapefile. When working in ArcGIS, this provides a valuable reference for aerial coverage in one's area of interest (Appendix A).

Images can be accessed for free and are shown to be compatible for orthoimagery production via PhotoScan. Some of these images can be downloaded at high resolutions, which produce the best orthoimages and are most suitable for the construction of historic DEMs. Unfortunately, only medium resolution scans are available for some images. These can be processed in PhotoScan, but tend to generalize small topographic anomalies. They were later found to be suboptimal for archaeological interpretation. An exception to this are medium-resolution downloads that are sufficiently large-scale (e.g., 1:15,000). (Appendix E includes comparisons of download quality and geographic scale.)

G. PRINCIPLES OF PHOTOGRAMMETRY

Photogrammetry is "the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena" (Wolf 1983:1). Systematic aerial surveys are conducted in parallel transects with a certain degree of overlap between them. Overlap between successive photographs in transect is called *end lap* with 55-65% overlap between images; overlap between transects is called *side lap* with about 30% overlap between transects (Wolf 1983:7). The former is provided in the EarthExplorer metadata under the field "Stereo Overlap" (Appendix B).

Basic photogrammetry involves corrections for interior and exterior orientation. The former deals with the internal operational settings of the camera, which primarily include the camera's focal length, lens distortion, principle point position, and the configuration of fiducials

(Wolf 1983:74–75). The exterior orientation describes where the camera is in relation to the ground surface, primarily the angle and distance of the camera from the ground (Wolf 1983:226). For a more detailed explanation of photogrammetric techniques, see Wolf (1983).

Aerial images utilized for this study were taken with single-frame cameras, which are essentially flat and reduce distortion. The focal length, average flying heights, and film dimensions are provided with the metadata for each image on the EarthExplorer website (Appendix B). To address issues of distortion with respect to exterior orientation, ground control points (GCPs) are used to establish where the camera is in space. Solving for these geometric parameters enables highly accurate orthoimages to be produced.

In addition to the production of orthoimages based on GCPs, photogrammetric methods also can be used to generate DEMs, also referred to as digital terrain models (DTMs). These are generated via tie points between two or more images that are measured from two different known camera angles, which in turn are used to triangulate the positions of the common points. Photogrammetric software programs such as Leica Photogrammetric Suite (LPS) and Agisoft PhotoScan automate this process, but with mixed results in terms of DEM quality. If elevations are not known for GCPs directly on the images themselves, then an external DEM can used to approximate elevation values for the GCPs on the basis of common points.

H. AGISOFT PHOTOSCAN PROFESSIONAL

Agisoft PhotoScan Professional is a photogrammetric software package provided by AgiSoft LLC (St. Petersburg, Russia). It generates orthoimages and DEMs using a series of overlapping images and calibration parameters for the camera as inputs. Although Agisoft LLC was founded in 2006, scholars already have taken advantage of PhotoScan’s algorithms to generate historic landscapes in archaeology. PhotoScan has been used profitably for both orthoimages and DEMs at the scale of excavations and individual archaeological sites.

For instance, several studies have effectively combined Unmanned Aerial Vehicle (UAV) photography and PhotoScan to create custom orthoimages and digital surface models for intrasite analysis. Bailey (2012) developed a custom UAV path-planning algorithm for the site of Mawchu Llacta in Peru, and he processed aerial images using PhotoScan. Another study compares image processing capabilities of BAE Systems' Socet Set versus Agisoft PhotoScan for UAV imagery of the archaeological site Himera in Sicily (Brutto et al. 2012). PhotoScan has been assessed as 3D mapping and visualization tool for documenting excavations and managing cultural heritage (De Reu et al. 2013). Verhoeven and colleagues have been the most prolific in their use of PhotoScan for generating 3D representations of oblique and near-vertical imagery of both sites and landscapes. For instance, recent applications include models of a kiln site and a stereopair of a 1960s landscape in Italy (Verhoeven 2011), a Roman quarry site (Verhoeven et al. 2012), and an imperial Roman town (Verhoeven 2012).

The software's main selling points are its advanced automated pixel matching and batch processing capabilities. The specific algorithms employed by the software are not provided because it is commercial software, which essentially creates a "black box" effect regarding certain processing stages. However, these limitations on user controls also make the software easy to use. The main disadvantage of the program is that it requires considerable random access memory (RAM) to run. A computer with 16.0 GB RAM was utilized for this study, which was relatively fast for processing 30 images or less, but was slower in generating orthoimages and DEMs exceeding this quantity, depending on the quality setting of the geometric solutions. In particular, the *Agisoft PhotoScan User Manual* (Agisoft LLC 2012:1) claims that "Assuming that a single photo resolution is of the order of 10 MPx, 2GB RAM is sufficient to make a model based on 20 to 30 photos. 12 GB RAM will allow to process up to 200-300 photographs." Furthermore, when the RAM requirements are not met for a particular stage in the processing, the program will not execute the task. Despite these limitations, the processing steps are easy to learn and the processing requires minimal attention by the user, excluding the georeferencing stage. The software can also batch process groups of images such that manageable pieces can be processed and then merged later.

I. ORTHOIMAGE PROCESSING OF EXTENSIVE REGIONS

The Center for Advanced Spatial Technology (CAST)'s Geospatial Modeling and Visualization (GMV) website (http://gmv.cast.uark.edu) provides a recommended workflow for image processing in PhotoScan (Opitz 2012), which was followed for this study. The processing steps are relatively straightforward, even for users unfamiliar with photogrammetric processing.

To begin, the user simply adds the photos to a workspace, specifies the camera calibration parameters, crops the images to exclude certain areas from processing, and executes the "Align Photos" command. In processing large regions for orthoimagery, it works best to process the images in blocks (e.g., 40-70 images), which can be merged later. The camera calibration inputs are somewhat counterintuitive, but they are not difficult to calculate. According to the *Agisoft PhotoScan User Manual* (Agisoft LLC 2012, 21) the necessary inputs are the "focal length in x- and y-dimensions measured in pixels," which are designated *fx* and *fy*, respectively. These parameters are defined as follows:

$$\mathrm{fx} = \text{focal length (mm)} * \frac{\text{x dimension of sensor (pixels)}}{\text{x dimension of sensor (mm)}}$$

$$\mathrm{fy} = \text{focal length (mm)} * \frac{\text{y dimension of sensor (pixels)}}{\text{y dimension of sensor (mm)}}$$

The camera focal lengths (mm) and the x-y dimensions of the sensor (mm) are provided with the metadata for each Single Frame on EarthExplorer (Appendix B). All frames utilized in this study are digital copies of 229 mm x 229 mm film. The x and y dimensions in pixels require information about the image resolution. According to the EarthExplorer website (http://eros.usgs.gov/):

> "EarthExplorer offers two digital download options for the Aerial Photography Single Frame Records collection…Medium Resolution Digital Aerial Products were created with a digital single-lens reflex camera at a resolution of 63 microns, or 400 dots per inch (dpi)…High Resolution Digital Aerial Products were created with a digital scanning back at a resolution of 25 microns, or 1,000 dpi. A geometric calibration is applied to each image to correct for distortions caused by the scanning process. The high resolution scans provide access to high precision data for photogrammetric applications."

For example, for a 1000 dpi High Resolution image produced from 229 mm by 229 mm film, *fx* would be calculated as follows:

$$\mathrm{fx} = \text{focal length (mm)} * \frac{\text{x dimension of sensor (pixels)}}{\text{x dimension of sensor (mm)}}$$

$$\mathrm{fx} = \text{focal length (mm)} * \frac{\cancel{\text{x dimension of sensor (mm)}} * (1000\ \mathrm{dpi})}{\cancel{\text{x dimension of sensor (mm)}}}$$

$$1000\mathrm{dpi} = \frac{1\ \mathrm{dot}}{0.001\ \mathrm{in}} = \frac{1\ \mathrm{dot}}{0.0254\ \mathrm{mm}}$$

$$\mathrm{fx} = 88.22\ \mathrm{mm} * \frac{1\ \mathrm{dot}}{0.0254\ \mathrm{mm}} \cong 3473.228$$

Because the frame camera is a square, *fx* = *fy*. The "principal point coordinates, i.e. coordinates of lens optical axis interception with sensor plane," *cx* and *cy*, are also required (Agisoft LLC 2012: 21). These were left at the default setting at the center of the image in pixels. Other unknown parameters—the "skew transformation coefficient… radial distortion coefficients [k1, k2, k3]… tangential distortion coefficients [p1, p2]" (Agisoft LLC 2012: 21)—were left at zero. Radial lens distortion and tangential lens distortion are "distortion[s] in image position along...[and] perpendicular to radial lines from the principal point [respectively]" (Wolf 1983:74). If unknown, the PhotoScan manual recommends inputs of zero for cameras with minimal lens distortion, and the latter two parameters are approximated by the software (Agisoft LLC 2012: 21).

Next, masks are created for the Single Frame images to exclude the fiducials (photograph markers) and the film's frame from processing (Figure 2). Otherwise, these areas will be counted as part of the image and will create unwanted artifacts on the 3D model and orthoimage.

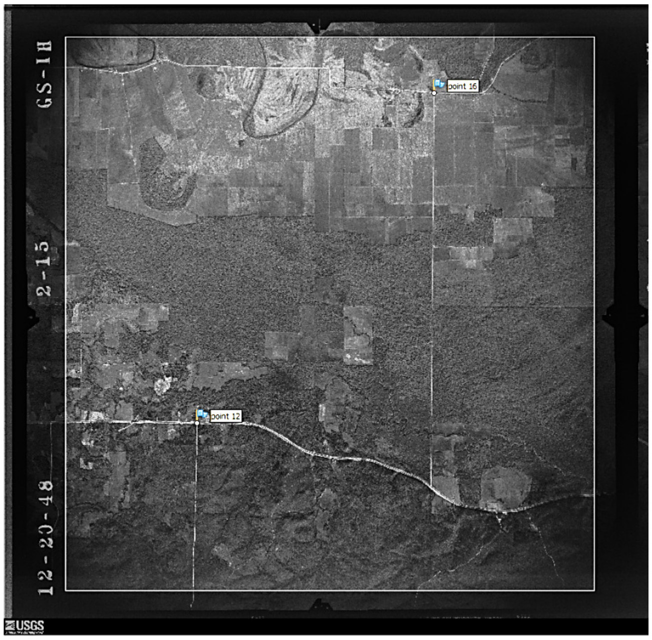


Figure 2 Sample Single Frame (USGS, AR1IH0000020015) with mask excluding the edges of the film, labels, and fiducials. GCPs are shown as blue numbered flags.

The "Generate Point Model" command is used to find common points between the imported images within the regions constrained by the masks. A user-defined bounding box specifies the points from this model that are used to generate a 3D surface. When generating the surface model, the "Height Field" setting is faster than the "Arbitrary Geometry" setting because the former produces the solution with respect to the orientation of the bounding box rather than for all orientations. Screenshots from these steps are shown in Figure 3.

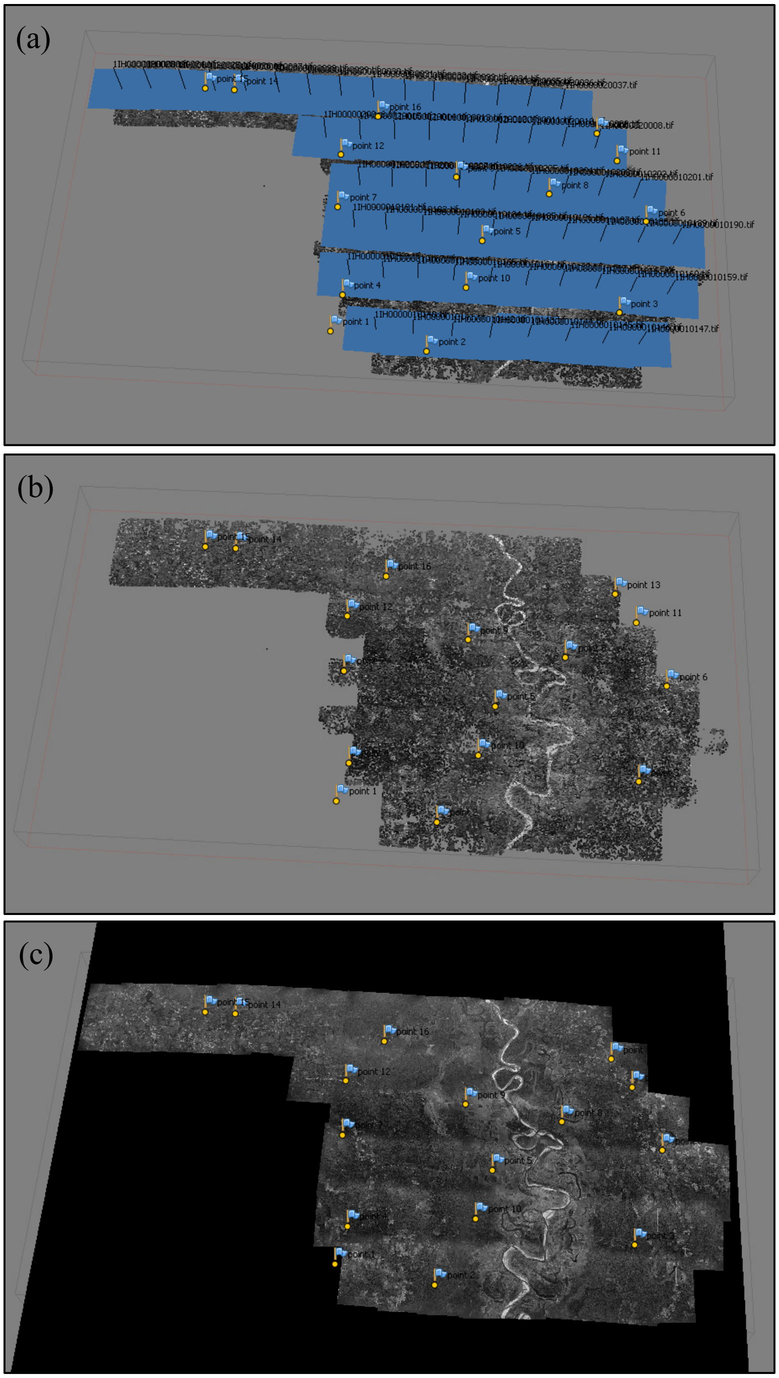


Figure 3 Processing steps in PhotoScan. This example consists of 62 photographs (Dec. 20 1948) in southwest Arkansas. A point model (270,267 points) is shown above with camera locations turned on (a) and turned off (b). The "Build Geometry" function produces a 3D model with a low-resolution orthoimage overlain for reference (c). This can be used to assess the placement of GCPs.

The GMV guide recommends that a low-resolution model be generated from the automated point cloud prior to georeferencing because it will enable the program to approximate common GCPs between images automatically, which can be adjusted at the discretion of the user (Figure 3). Georeferencing can be done with respect to another reference image rectified to a known coordinate system. In this case, the Arkansas State Land Information Board's "2006 Natural Color County Mosaic" and corresponding 5 m DEM were used to establish GCPs. Both datasets were generated with an ADS40 Airborne Digital Sensor between January 15 and March 31, 2006, and are available for download on GeoStor (www.geostor.arkansas.gov/). As a general rule, GCPs should represent fixed and specific locations (e.g., road intersections, buildings, bridges) that one can confidently identify as a common location between the historic and modern images. The placement of GCPs is done directly on the images, and the low-resolution 3D model can be used as a reference to ensure that the GCPs are distributed evenly across the processing region. On average, 10-15 GCPs were sufficient to produce accurate orthoimages for archaeological prospecting.

These GCPs are then used to reorient the point scatter model with respect to the specified geographic projection. The "Optimize" and "Update" commands can be used to incorporate the GCPs into the point cloud for the 3D model and to view errors for each GCP, with a <20 pixel error preferred (Opitz 2012). From this, a higher-resolution 3D model can be generated. At the county scale, the following settings were used: "Medium Geometry" or "Low Geometry" depending on the number of images, "Smooth," 200,000 face count, a "Filter Threshold" of 0.1, and a "Hole Threshold" of 0.1 (Figure 4). With the "Build Texture" command, the imagery is draped over this model to produce an orthorectified image. The orthoimage type was set to "Adaptive Orthophoto" to improve the textures of objects with relatively sharp vertical geometries. When the surface geometry is complete, one can crop unwanted geometry at the edges prior to DEM exportation into ArcGIS. As an aside, the general term "digital elevation model" (DEM) is used for this study because it is more familiar to an archaeological audience and it is consistent with the terminology used in PhotoScan. However, the resultant geometric models are technically digital surface models (DSMs), which include 3D objects on the earth's surface (e.g., trees and houses) in addition to the general landscape topography. In contrast, digital terrain models (DTMs) are representations of the ground surface alone.

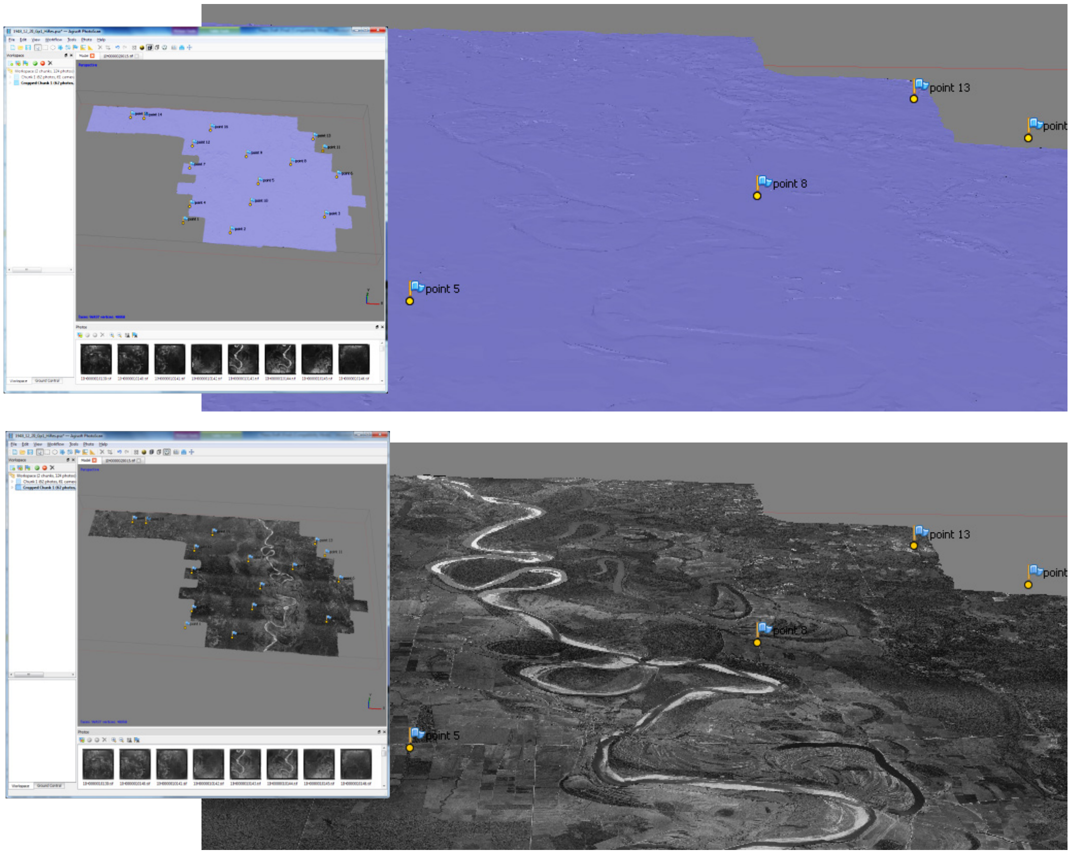
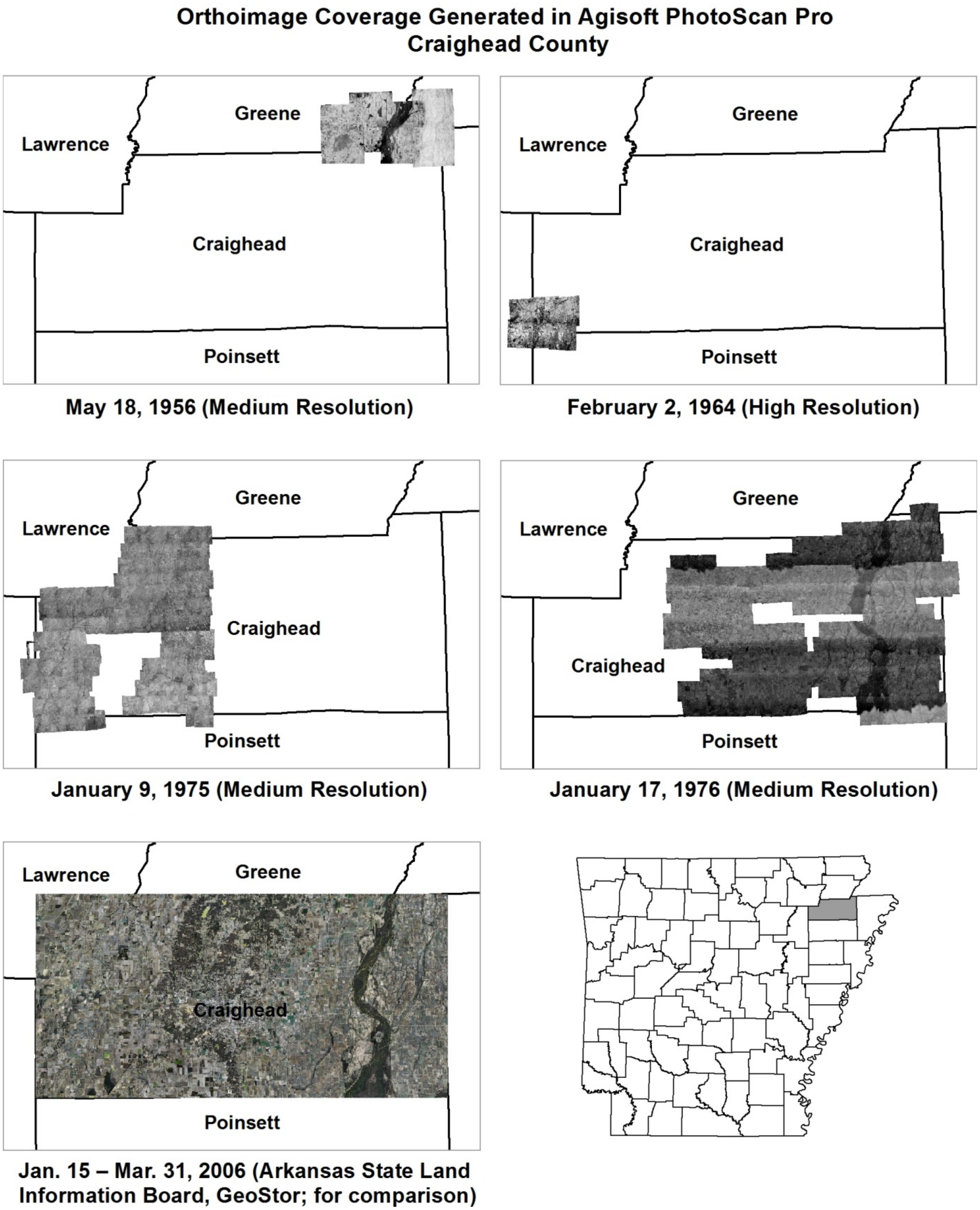


Figure 4 Screenshots of the Medium Geometry model and Build Texture results

In conducting these steps, it is advisable to keep a spreadsheet documenting the names of the aerial blocks being processed by year, the inputs used for the camera calibration, and the processing steps. For instance, in these examples, "1" was used to indicate the successful completion of a step and “0” was used to denote some sort of error that occurred that needed to be revised. One can also include comments for specific cells, documenting parameters that were used.

When the processing is complete, the orthoimage should always be examined in comparison to an accurate reference image to assure that the georeferencing quality meets the requirements of the project application. For example, in processing a group of 42 images for Mississippi County on the order of 400 km^2, parts of photos were misaligned by 70-120 meters in comparison to a modern orthorectified image. Although one can still compare images at this level of spatial discrepancy, it is cumbersome to make this mental adjustment when analyzing many sites. In such instances, GCPs were reviewed for accuracy and additional GCPs were acquired to improve performance.

Figures 5-7 show countywide orthoimages produced in this fashion for this study with the download quality resolution provided in parentheses. For some areas, particularly in northeast Arkansas, only images immediately adjacent to clusters of archaeological sites were processed for the sake of time efficiency. For southwest Arkansas, larger processing groups (e.g., 40-70 images) were used. From these images, it is clear that the program can pixel-match and mosaic images with different levels of brightness and contrast; therefore, images usually do not require tone matching prior to processing for the algorithms to work.


Orthoimage Coverage Generated in Agisoft PhotoScan Pro
Craighead County

May 18, 1956 (Medium Resolution)

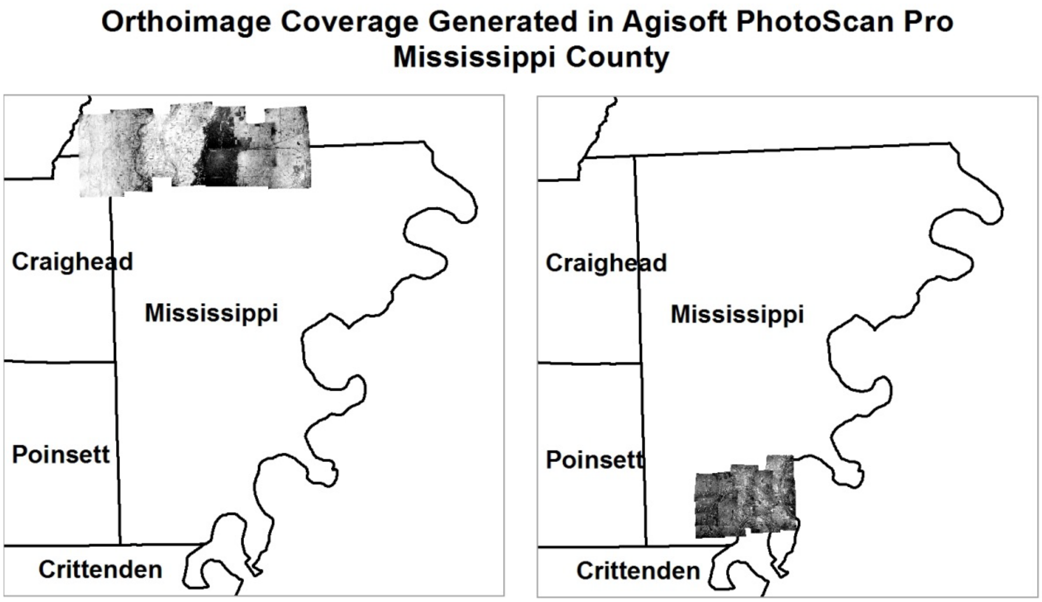
February 2, 1964 (High Resolution)

January 9, 1975 (Medium Resolution)

January 17, 1976 (Medium Resolution)

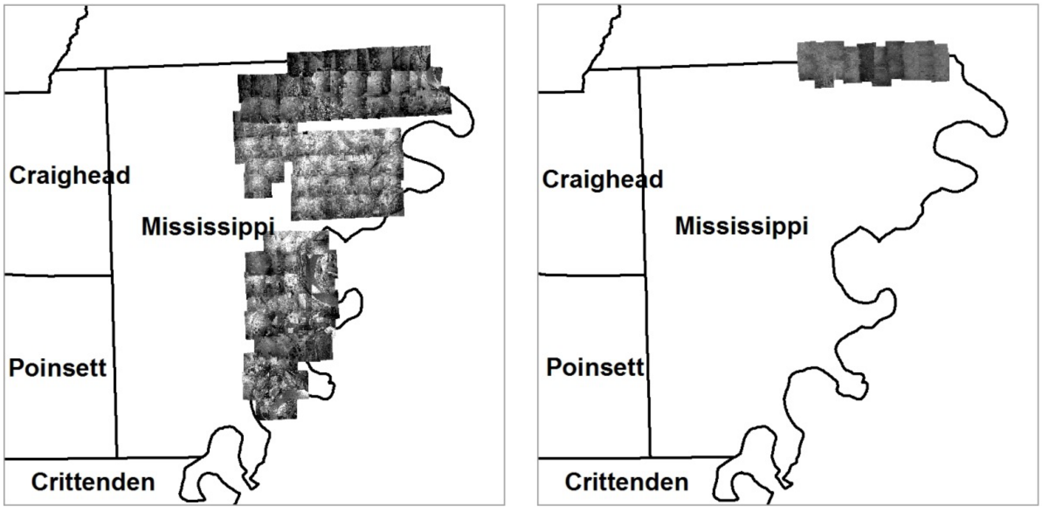
Jan. 15 – Mar. 31, 2006 (Arkansas State Land Information Board, GeoStor; for comparison)

Figure 5 PhotoScan-generated orthoimagery for Craighead County



May 18, 1956 (Medium Resolution)

April 11, 1969 (High Resolution)

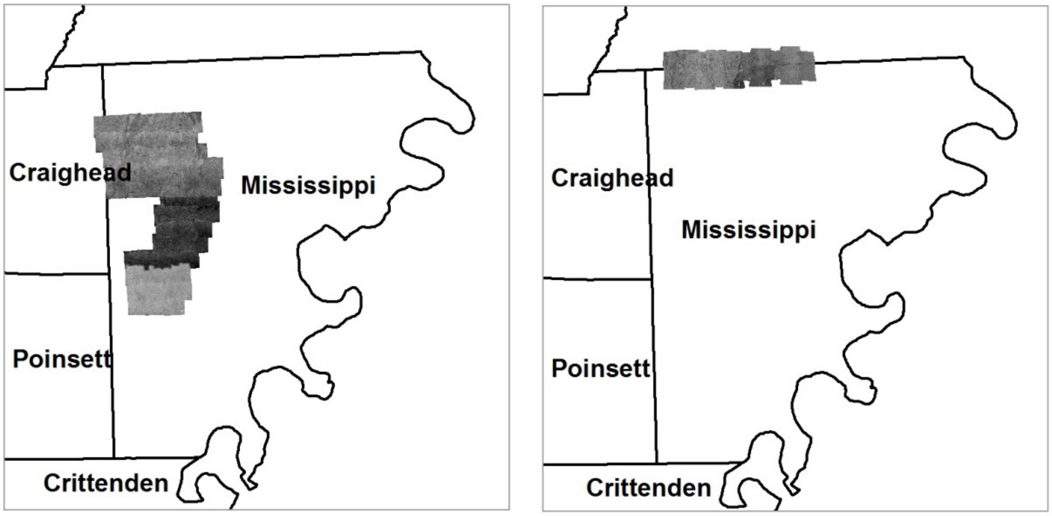


April 7, 1971 (High Resolution)

February 8, 1975 (Medium Resolution)

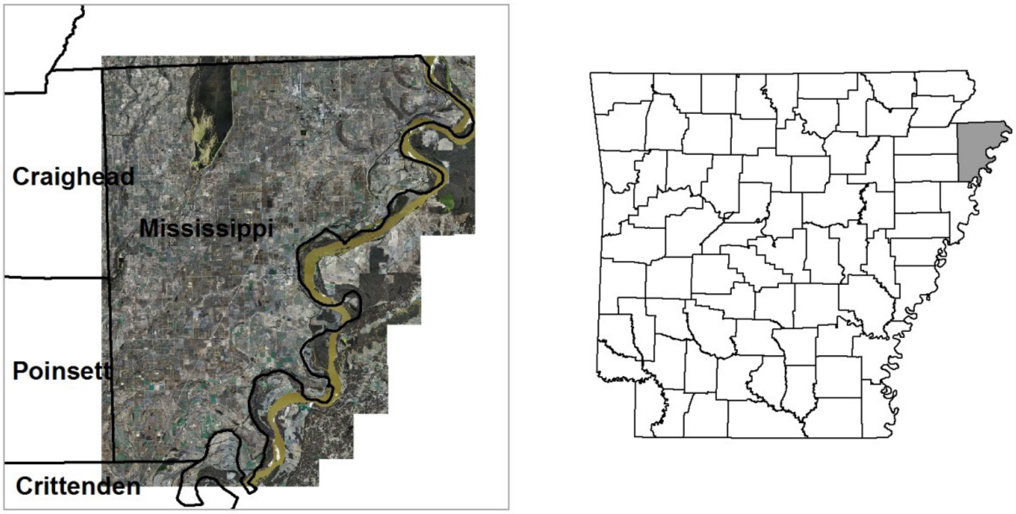
Figure 6 PhotoScan-generated orthoimagery for Mississippi County

Orthoimage Coverage Generated in Agisoft PhotoScan Pro
Mississippi County (Continued)



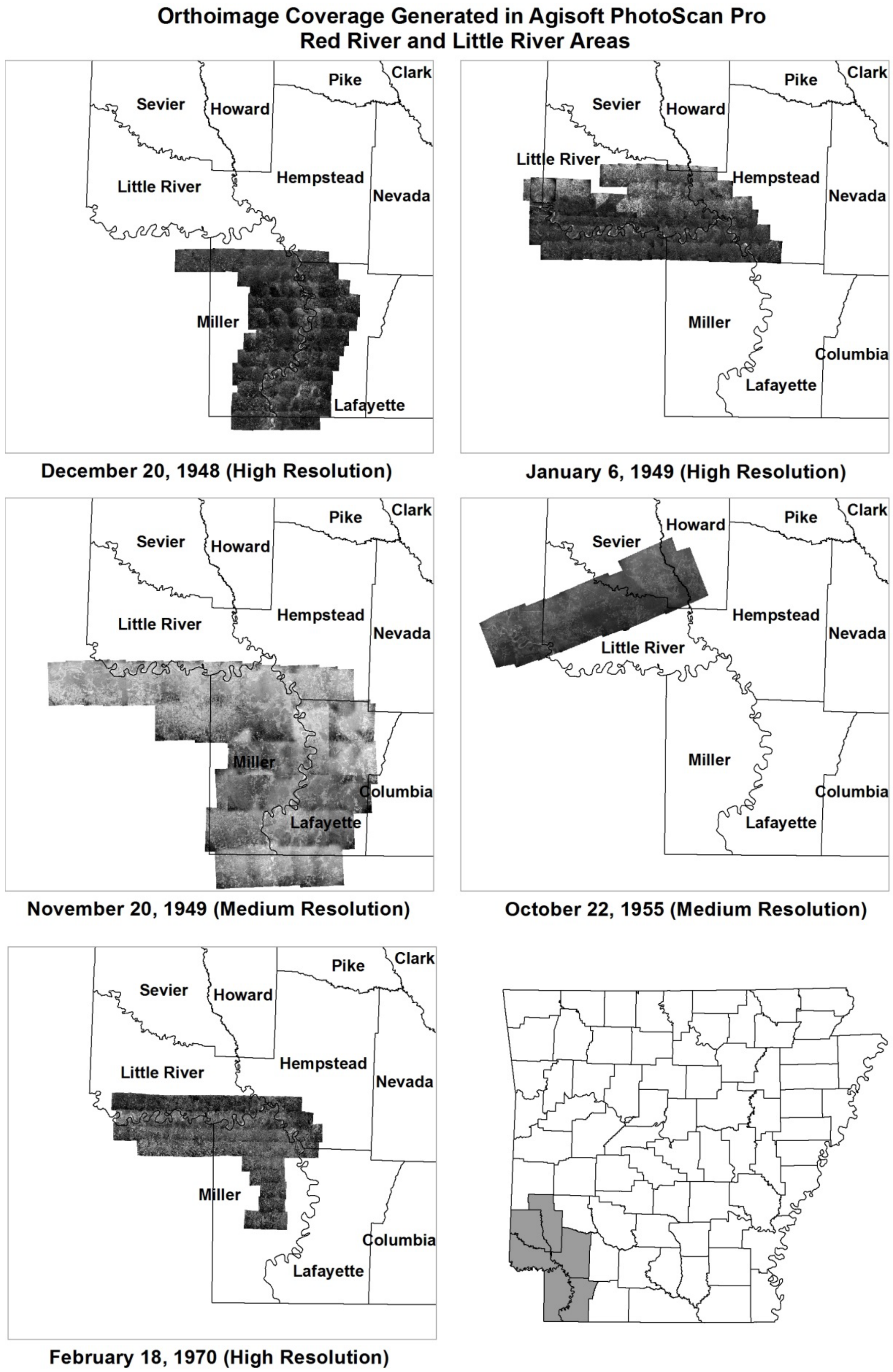
January 17, 1976 (Medium Resolution)

April 13, 1978 (Medium Resolution)



Jan. 15 – Mar. 31, 2006 (Arkansas State Land Information Board, GeoStor; for comparison)

Figure 6 (continued) PhotoScan-generated orthoimagery for Mississippi County



December 20, 1948 (High Resolution)

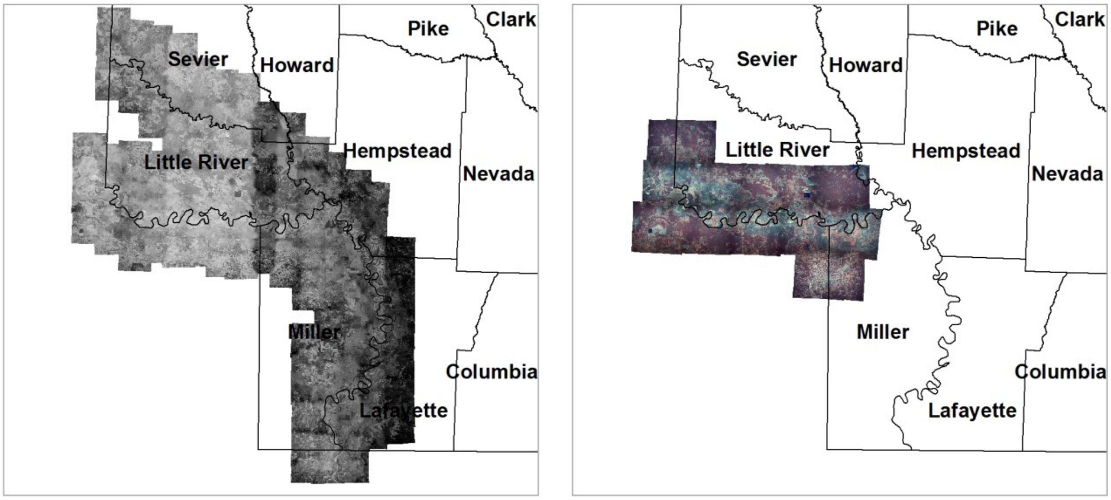
January 6, 1949 (High Resolution)

November 20, 1949 (Medium Resolution)

October 22, 1955 (Medium Resolution)

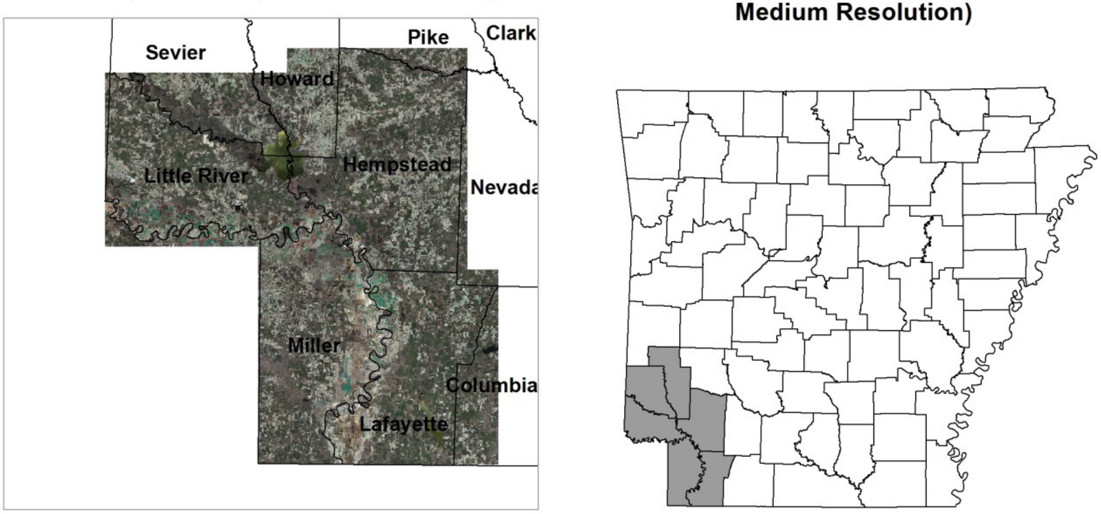
February 18, 1970 (High Resolution)

Figure 7 PhotoScan-generated orthoimagery for the Red River and Little River areas


Orthoimage Coverage Generated in Agisoft PhotoScan Pro
Red River and Little River Areas (Continued)

February 25, 1975 (Medium Resolution)

November 10, 1979 (Near Infrared, Medium Resolution)



Jan. 15 – Mar. 31, 2006 (Arkansas State Land Information Board, Geostor; for comparison)

Figure 7 (continued) PhotoScan-generated orthoimagery for the Red River and Little River Areas

J. INITIAL ASSESSMENTS OF SITE VISIBILITY

For all processed orthoimages, sites were assigned simple ranks for each date according to their perceived visibility: invisible, possibly visible, and visible sites. Classifications were made using the following criteria:

1) *Invisible sites*: Either the site shows no distinct change (e.g., color, elevation, shadowing) from the surrounding landscape adjacent to the site center, or such contrasts were interpreted as geomorphological.
2) *Possibly visible sites:* Areas adjacent to the site represent a change from the surrounding landscape, such as a change in soil color, vegetation, or drainage properties. However, they were categorized as undetermined because (1) the shape of the landscape anomaly is not immediately recognizable as a manmade structure, (2) the anomaly could be geomorphological, and/or (3) the anomaly could represent relatively modern (post-1900) disturbances to the landscape.
3) *Visible sites:* The site represents a distinct change from the surrounding landscape, and it exhibits a shape of a size consistent with building structures or documented built environments. In the case of historic buildings, a structure was clearly apparent in proximity to the recorded site location. Upon follow-up analysis, these sites exhibit features that have been previously documented that correspond with the anomalies.

This initial stage is a subjective assessment, and the codification process will vary somewhat from person to person. However, objective measures of site visibility have not yet been established that would account for the variability of site types within the study areas. Therefore, this visual approach provides a pragmatic means to site classification, and it has certain advantages. Firstly, it allows for the quick examination and codification of all sites to establish areas that have visible components or that have the most potential for being visible in other orthoimages. In turn, these sites and regions will form the basis for characterizing sites, environmental conditions, and aerial photograph conditions that are optimal for site visibility. Secondly, this stage of analysis is largely an inductive means of reviewing characteristics of all sites individually, providing an exploratory basis for future classifications. Furthermore, the task of classification under these criteria can be undertaken by almost anyone regardless of his/her experience with aerial prospecting, and the process of classification itself presents a means for learning site morphologies. Lastly, with good location reliability assessed at less than 40 acres as specified for an AMASDA query (Hilliard and Riggs 1986:6), one would assume that sites classified as invisible using the above criteria are unlikely to be classified as visible if they were reviewed again.

K. INTRASITE ANALYSIS OF VISIBLE SITES

1. High-Resolution DEM Generation

For each site, a small subregion was processed in PhotoScan to generate a high-resolution topographic model. This was initially attempted with groups of five to eight images to create a DEM that included the sites within their surrounding landscapes. Although more detailed than the DEMs produced at the countywide scale, the precision of these geometric models were insufficient for archaeological interpretation. To decrease processing time, image collections were reduced to two or three images with processing boundaries placed directly over the immediate archaeological site extent. (It should be noted that a user-defined bounding box is what ultimately determines the processing extent, rather than the extent of the images themselves.) For areas in which a lower-resolution model had already been generated for extensive regions, a copy of the processing chunk was created and extraneous images and GCPs were simply removed prior to high-resolution processing. This allows one to skip the initial camera calibration, photograph alignment, and low-geometry generation steps. After additional GCPs are added and revised for the area of interest, the processing box can be made smaller to include only a specific archaeological site to generate a custom DEM.

A major limitation for the generation of high-resolution geometric models is processing time. However, a selection of two to three images was generally sufficient to cover the extents of specific archaeological site within the regions studied. By restricting processing to very small areas (e.g., <500 hectares), the geometry can be processed at the ultra-high setting with a larger amount of faces in the model (e.g., 200,000,000 versus 200,000), which would be far too slow to process for larger regions.

Custom DEMs were imported into ArcGIS software. Pixel values were cropped to emphasize contrasts in intermediate values for areas with possible archaeological features. Hillshade models were also generated to see if certain azimuths (light source angle with respect to cardinal directions) and altitudes (light source with respect to the horizon) would reveal topographic anomalies. As was the case for the larger-scale DEMs, the hillshades were most effective in delineating linear objects such as roads and drainage features. Combined with the orthoimages, these data were used as corroborative evidence for digitizing interpretations.

2. Digitization of Possible Archaeological Features

Visible sites that contained immediately apparent archaeological features were reexamined in more detail. Similar to Wilson's index of site types apparent in aerial imagery, the objective at this stage was to explore what kinds of structures and features could be visible on the aerial images such that this knowledge could be applied to other sites. Site forms for each of these sites were investigated to determine whether the some of the anomalies were already accounted for and to provide a general archaeological context for interpreting unknown anomalies. Overall, strategies for detecting intrasite features relied on hypotheses and groupings by color, shape, size, pattern, texture, and shadows (Riley 1987:60–61).

Color/Tone In the early stages of digitization, most anomalies of high or low reflectance were delineated in ArcGIS, regardless of their potential origin. The reasoning behind this is to holistically examine each image and to force the observer to explicitly account for and hypothesize about each anomaly.

Shape, Size, Pattern Of the general anomalies identified by reflectance, anomalies were further categorized on the basis of similar shapes, sizes, and patterns. For instance, linear features were further interpreted as modern canals and stream channels, roads, footpaths, and drainages based on their reflectance, the level of vegetation associated with them, the clarity of their edges, and the overall configuration of connected segments. The historic DEMs were used as a guide for this, particularly for more ephemeral anomalies such as minor drainages. Because both artificial mounds and prairie mounds have deceptively similar shapes, sizes, coloration, and topographic expression, the level of clustering was important in determining general prairie mounds from more prominent mounds that may have had cultural significance.

Texture Texture was important in distinguishing topographically smooth versus topographically noisy areas, as well as differences in vegetation. Especially in agricultural areas, local variance in topography can represent areas in which land-leveling was obstructed. For example, early agriculturalists sometimes avoided mounds, leaving trees to grow on them. In the case of Battle Mound, barrow pits are sometimes used as wading pools for cows or are left vegetated. Texture also was useful in assessing the accuracy of the DEMs, which did not perform well at modeling areas with extensive tree coverage.

Shadowing Although many mounds and associated structures have been completely land-leveled due to continued agricultural practice, one would expect that some mounds still remained at the time that the historic aerial images used in this study were taken. Similar to the identification of tells in the Middle East, possible mounds in open fields can appear as light circular anomalies with characteristic shading on one side, indicating the orientation of the sun at the time of the photograph capture. When this kind of morphology was observed, it was digitized and compared with the historic DEM to see if it represented a topographically elevated area.

Collectively, these digitizations can be codified to indicate potential features that hold the most promise for archaeological inquiry. In turn, this provides a visual stimulus for dialogues with other observers to reassess the images and to develop new hypotheses to be tested. Furthermore, this helps the analyst to determine if certain anomalies are instances of overlap of modern and natural features, which can produce misleading shapes and patterns that could be mistaken for archaeological features. Other strategies specific to this analysis for distinguishing archaeological anomalies from natural and modern anomalies are described in the subsequent section.

III. RESULTS

A. DISCOVERIES FROM THE INITIAL VISUAL ASSESSMENT

Although not all kinds of sites are amenable to aerial prospecting (e.g., lithic scatters), the site visibility rankings indicate that large sites with intensive land modification are highly visible. In turn, aerial imagery is very useful for reassessing known archaeological sites, as well as regions with high densities of recorded archaeological sites. Overall, the methods employed here have considerable potential for discovering large, undocumented sites on a regional scale and for conducting detailed prospecting over small areas. Visibility for other site types could be improved with a different range of dates, seasons, and land-use conditions.

Since determinations of site visibility will vary depending upon the observer, the degree of "success" in identifying visible sites is subjective. The ranking system employed here is crude at best, and it is biased towards site types that the researcher expects to see (e.g., mounds) and the researcher's knowledge of local archaeology. However, this method provides a useful learning exercise for individual scholars to develop site recognition skills. Ranking sites into three simple categories helps the researcher to gain rapid familiarity with a wide range of possible site morphologies over multiple image dates. Furthermore, this system provides a sort of narrowing scheme, allowing one to focus on similarities between archaeological sites. These steps are crucial to define diagnostic characteristics for site types, providing the foundation for future systematic classification and possibly even criteria for automated classification.

At the present stage, one would expect that sites confidently classified as visible or invisible would be fairly similar between researchers, but the extent to which classifications would differ has yet to be substantiated. The following data represent a personal assessment, which can be taken at the reader's discretion as a preliminary approximation of site visibility.

Most of the sites were either classified as possibly visible or invisible (Table 3; Figures 8-9). A small percentage of sites—primarily of mound sites and historic structures—were classified as visible. The percentages of visible sites are comparable for northeast and southwest Arkansas (2.6% versus 2.2%, respectively), but the percentage of possibly visible sites is higher for the latter (40.8%) versus the former (26.2%).

Table 3 Site visibility assessment results for northeast and southwest Arkansas

Study Areas	Invisible	Possibly Visible	Visible	Total Analyzed
Northeast Arkansas	801 (71.3%)	294 (26.2%)	29 (2.6%)	1,124
Southwest Arkansas	371 (57.0%)	265 (40.8%)	14 (2.2%)	650

Photograph characteristics and site types are investigated in the subsequent sections and certainly play key roles in these results. Local environmental conditions and researcher confidence also contribute to these determinations. Sites in southwest Arkansas were classified *after* sites in northeast Arkansas. Therefore, the higher percentage of possibly visible sites later in the classification process could represent an increased familiarity with aerial interpretation and site morphologies. In turn, sites in northeast Arkansas could be reassessed for visibility to see whether the relative percentages of possibly visible and visible sites increase. Furthermore, clusters of possibly visible sites could be compared more intensively with the AMASDA site files and be reclassified as visible based on the researcher's level of confidence.

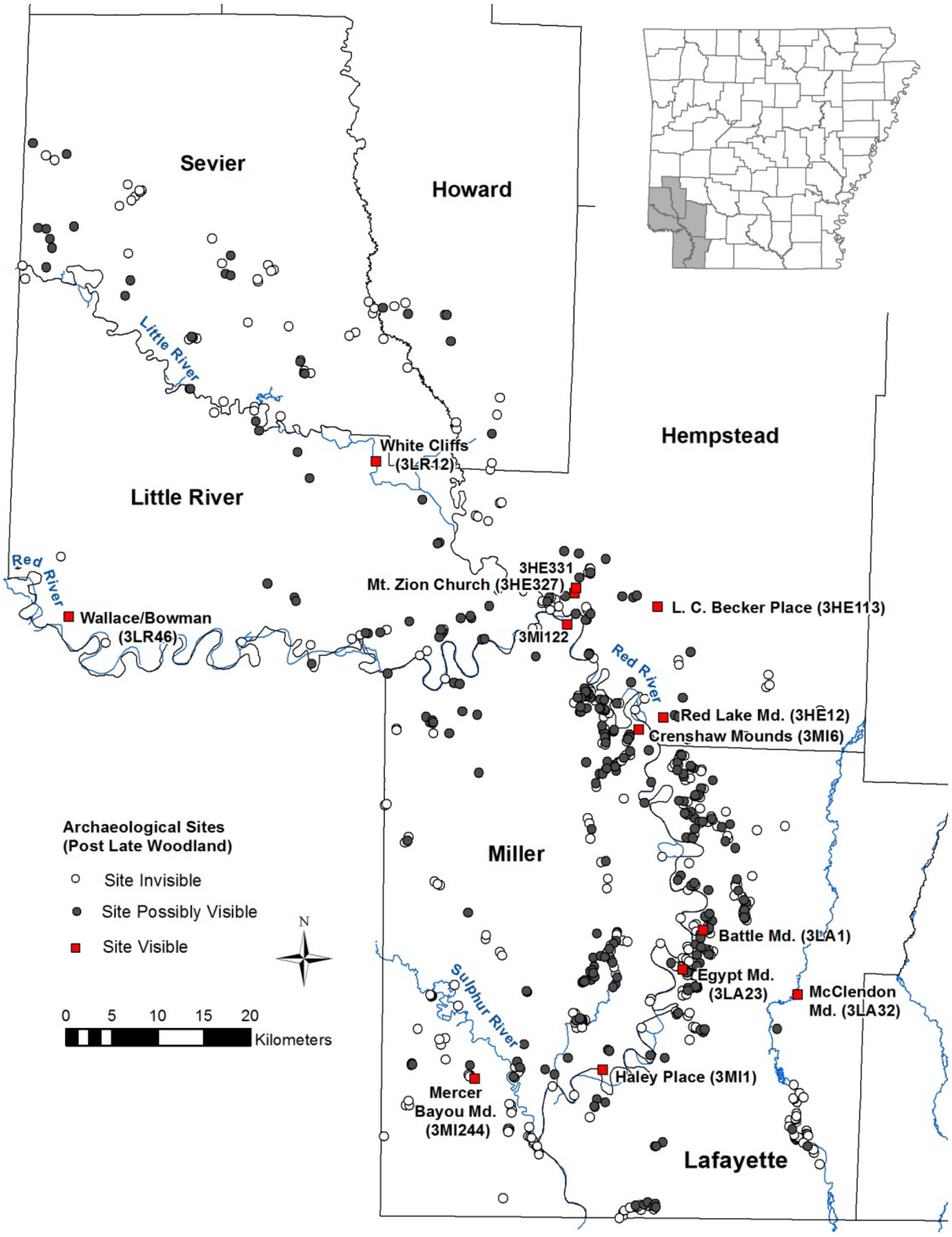


Figure 8 Site visibility classifications for counties along the Red River and Little River

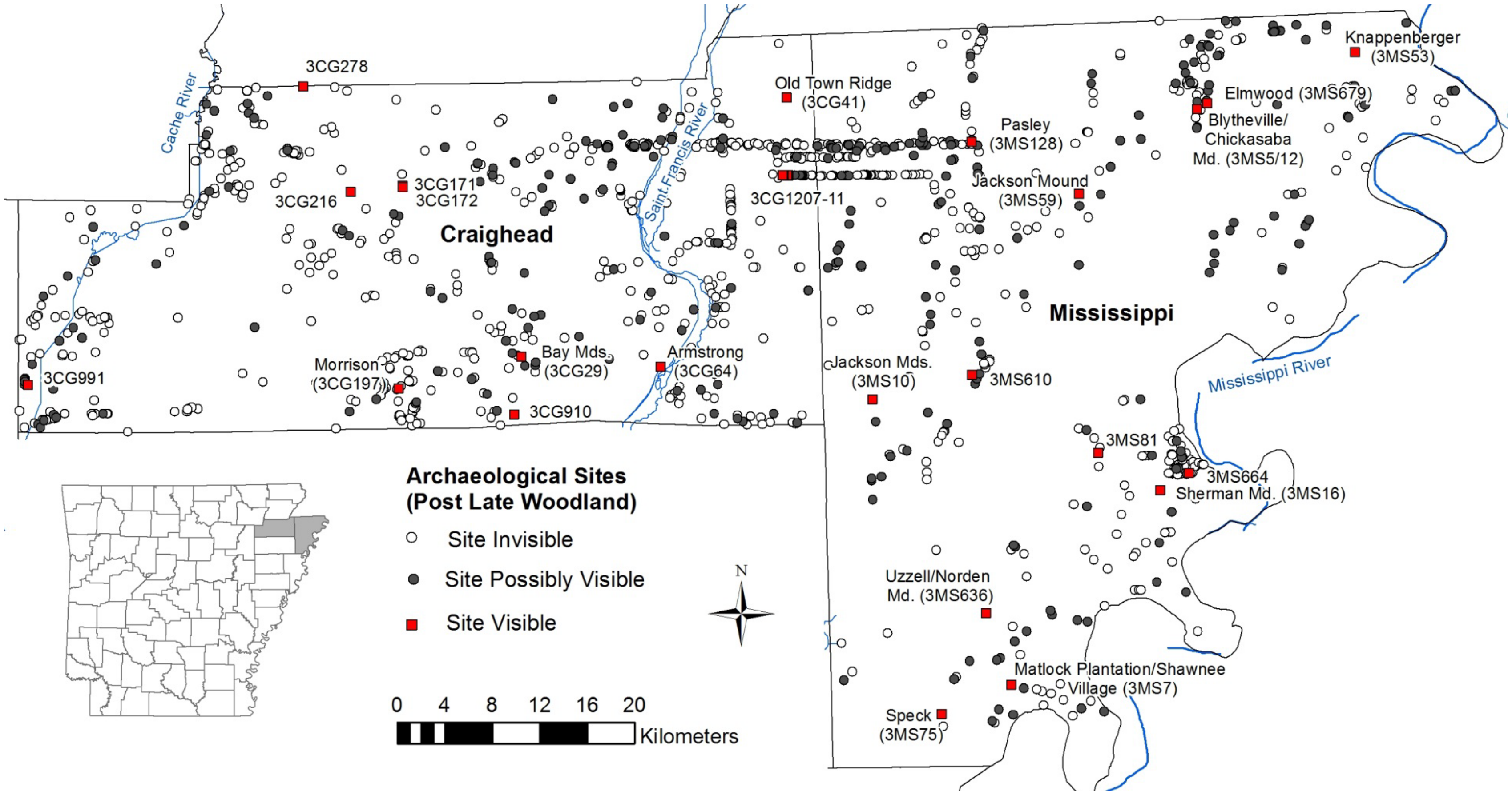


Figure 9 Site visibility classifications for Mississippi and Craighead Counties

1. Types of Imagery Amenable to Prospecting

Archaeological site visibility is fundamentally linked to the qualities of the imagery, particularly the year of the photograph, seasonality, time of day, and image resolution and contrast. Tables 4-6 provide the number of sites classified as invisible, possibly visible, and visible for each year for Craighead County, Mississippi County, and the Red River counties, respectively. Some of the samples sizes are small because the amount of coverage was limited or because the images available overlapped with few archaeological sites in the chosen study areas. Furthermore, in making these comparisons, one must note that the geographic extents for each year is not held constant. Therefore, increased visible site counts may be an indicator of physiographic characteristics, differential preservation, and local archaeological site types that are more amenable to aerial prospecting. Trends related to site type are discussed later.

As one would expect, medium-resolution downloads (400 dpi photographs) were more difficult to interpret than the high-resolution downloads (1,000 dpi scans) from EarthExplorer. For the former, visibility was primarily classified on the basis of visually matching pixels with higher-resolution downloads, indicating that the flagged anomalies were recognizable. (In this respect, the medium-resolution download data are overestimates of visibility and serve as references for potential years in which additional high-resolution imagery could be acquired. If the medium resolution images were the only reference, then the number of visible sites would be much lower.) On the other hand, some medium-resolution images were comparable to the high-resolution images due to the difference in the scale of the original photograph. Generally speaking, high-resolution downloads of 1:35,000 scale or larger were ideal; for medium-resolution downloads, 1:15,000 or larger were ideal.

Contrast levels of the original photographs were important, and downloads from the winter months generally provided sufficient contrast for analysis. For instance, the January 17, 1976 imagery was a medium-resolution download, but exhibited strong contrast, which was useful for the detection of anomalies. The May 18, 1956 imagery, besides being of too small a scale, had exceptionally low contrast, making it a poor resource for prospecting. Images were not processed prior to their use in PhotoScan, but contrast levels of the exported orthoimages were adjusted afterwards in ArcGIS. Pre-processing of images may make them better for subsequent modeling, but operable contrast levels will be limited by the original photograph.

Table 4 Site visibility assessment results for Craighead County sites

Craighead County Sites						
Date	Download Resolution	Scale	Invisible	Possibly Visible	Visible	Total Analyzed
May 18 1956	Medium	30,000	5	0	1	6
Feb. 2 1964	High	23,000	20	10	0	30
Jan. 9 1975	Medium	15,000	152	23	1	176
Jan. 17 1976	Medium	15,000	405	64	13	483
Jan.-Mar. 2006	----	----	520	93	12	625

Table 5 Site visibility assessment results for Mississippi County sites

Mississippi County Sites						
Date	Download Resolution	Scale	Invisible	Possibly Visible	Visible	Total Analyzed
May 18 1956	Medium	30,000	32	3	0	35
Apr. 11 1969	High	20,500	8	10	1	19
Apr. 7 1971	High	21,200	144	43	6	193
Feb. 8 1975	Medium	15,000	27	7	0	34
Jan. 17 1976	Medium	15,000	171	39	3	217
Apr. 13 1978	Medium	15,000	11	2	0	13
Jan.-Mar.2006	----	----	347	141	11	499

Table 6 Site visibility assessment results for sites along the Red River and Little River

Red River and Little River Sites						
Date	Download Resolution	Scale	Invisible	Possibly Visible	Visible	Total Analyzed
Dec. 20 1948	High	32,800	285	89	5	379
Jan. 6 1949	High	32,800	106	54	8	168
Nov. 20 1949	Medium	70,000	474	31	4	509
Oct. 22 1955	Medium	85,997	34	7	0	41
Feb. 18 1970	High	29,600	123	75	3	201
Feb. 25 1975	Medium	43,000	452	115	2	569
Nov. 10 1979	Medium	65,000	43	11	0	54
Jan.-Mar. 2006	----	----	505	116	10	656

2. Types of Sites Amenable to Archaeological Prospecting

For photographic years with large sample sizes (N ≥150) and visible sites, characteristics of the visible sites were compared against the total site sample. The data used in these comparisons come from the AMASDA site metadata. Here, the characteristics "Yes" and "Questionable" were aggregated, assuming that factors related to the latter categorization would likely be visible for analysis.

For the January 17, 1976 imagery of Craighead County (Table 7), mounds and surface scatters (<100 sq. m.) compose 2.1% and 13.9% of the total sample, respectively, yet 53.8% and 38.5% of the visible sites. Sites with associated archival references show a similar increase between the total (11.6%) and visible (38.5%) sites. Although 30.8% are large surface scatters (>100 sq. m), this is less than expected based on the total (75.4%). These same relationships are reflected in the 2006 comparisons between the total and sample: 2.9% versus 75% for mounds, 12.8% versus 25% for small scatters, 9.1% versus 25% for archived records, and 77.4% versus 25% for large surface scatters.

For April 7, 1971 in Mississippi County (Table 8), mounds compose 4.1% of the total sample, yet 83.3% of the visible sites are mounds. Scatters with middens show a similar increase between total and visible sites (25.4% versus 66.7%) and less so for site with extant structures (11.4% versus 33.3%). Despite the small sample size (n=3), the imagery for January 17, 1976, similarly shows that—for the total sites versus visible sites, respectively—2.8% versus 66.7% are mounds, 18.4% versus 66.7% are scatters with middens, and 13.8% versus 66.7% have structures present. The 2006 classifications likewise show that mounds, scatters with middens, and extant structures are amenable to visibility with the following comparative percentages of total versus visible sample: 5.2% versus 81.8%, 23.6% versus 63.6%, and 12.4% versus 54.5%, respectively.

All Red River sites classified as visible for December 20, 1948 (Table 9) were mounds, even though mounds only compose 6.3% of the total sites for that date. Most of the visible sites were also surface scatters exceeding 100 sq m (80% of visible sites) and less than half were scatters with middens (40%). Both exhibited a larger precentage than the 1948 percentages (73.4% and 21.1%, respectively). The January 6, 1949, and November 20, 1949, data also reflect this, consisting primarily of mounds and large artifact scatters (62.5% and 62.5% for January; 100% and 100% for November). A subset of these also had middens associated with the scatters (37.5% for January and 50% for November). Likewise, all of the visible sites for 2006 were mounds (7.4% of the total 2006 sample) and almost half had scatters with middens (40% versus 21.4% for the total). Most were large surface scatters (60%), which is proportionally consistent with the total sample for that date (68.5%).

Table 7 Site attribute comparison of all sites vs. visible sites in Craighead County

Craighead County: January 17, 1976

All Sites Examined (N=482):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	3 (0.6%)	67 (13.9%)	364 (75.4%)	30 (6.2%)	14 (2.1%)	0 (0%)	0 (0%)	4 (0.6%)	1 (0.2%)	2 (0.4%)	56 (11.6%)	24 (5%)
No	479 (99.4%)	415 (86.1%)	118 (24.6%)	452 (93.8%)	468 (97.1%)	482 (100%)	482 (100%)	478 (99.2%)	481 (99.8%)	480 (99.6%)	426 (88.4%)	458 (95%)

Visible Sites (N=13):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	0 (0%)	5 (38.5%)	4 (30.8%)	0 (0%)	7 (53.8%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (38.5%)	1 (7.7%)
No	13 (100%)	8 (61.5%)	9 (69.2%)	13 (100%)	6 (46.2%)	13 (100%)	13 (100%)	13 (100%)	13 (100%)	13 (100%)	8 (61.5%)	12 (92.3%)

Table 7 (ctd.) Site attribute comparison of all sites vs. visible sites in Craighead County

Craighead County: January-March, 2006

All Sites Examined (N=625):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	4 (0.6%)	80 (12.8%)	484 (77.4%)	40 (6.4%)	18 (2.9%)	0 (0%)	0 (0%)	4 (0.6%)	2 (0.3%)	2 (0.3%)	57 (9.1%)	22 (3.5%)
No	621 (99.4%)	545 (87.2%)	141 (22.6%)	585 (93.6%)	607 (97.1%)	625 (100%)	625 (100%)	621 (99.4%)	623 (99.7%)	623 (99.7%)	568 (90.9%)	598 (96.5%)

Visible Sites (N=12):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	0 (0%)	3 (25%)	3 (25%)	0 (0%)	9 (75%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (25%)	0 (0%)
No	12 (100%)	9 (75%)	9 (75%)	12 (100%)	3 (25%)	12 (100%)	12 (100%)	12 (100%)	12 (100%)	12 (100%)	9 (75%)	12 (100%)

Table 8 Site attribute comparison of all sites vs. visible sites in Mississippi County

Mississippi County: April 7, 1971

All Sites Examined (N=193):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	9 (4.7%)	5 (2.6%)	128 (66.3%)	49 (25.4%)	8 (4.1%)	0 (0%)	0 (0%)	0 (0%)	1 (0.5%)	4 (2.1%)	5 (2.6%)	22 (11.4%)
No	184 (95.3%)	188 (97.4%)	65 (34.7%)	147 (74.6%)	185 (95.9%)	193 (100%)	193 (100%)	193 (100%)	192 (99.5%)	189 (97.9%)	188 (97.4%)	171 (88.6%)

Visible Sites (N=6):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	0 (0%)	0 (0%)	1 (16.7%)	4 (66.7%)	5 (83.3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (33.3%)
No	6 (100%)	6 (100%)	5 (83.3%)	2 (33.3%)	1 (16.7%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)	4 (66.7%)

Table 8 (ctd.) Site attribute comparison of all sites vs. visible sites in Mississippi County

Mississippi County: January 17, 1976

All Sites Examined (N=217):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	14 (6.5%)	57 (26.3%)	112 (51.6%)	40 (18.4%)	6 (2.8%)	0 (0%)	0 (0%)	0 (0%)	2 (0.9%)	2 (0.9%)	51 (23.5%)	30 (13.8%)
No	258 (94.9%)	214 (78.7%)	133 (48.9%)	177 (81.6%)	211 (97.2%)	217 (100%)	217 (100%)	217 (100%)	215 (99.1%)	215 (99.1%)	166 (76.5%)	187 (86.2%)

Visible Sites (N=3):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	0 (0%)	0 (0%)	2 (66.7%)	2 (66.7%)	2 (66.7%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (66.7%)
No	3 (100%)	3 (100%)	1 (33.3%)	1 (33.3%)	1 (33.3%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	1 (33.3%)

Table 8 (ctd.) Site attribute comparison of all sites vs. visible sites in Mississippi County

Mississippi County: January-March, 2006

All Sites Examined (N=499):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Questionable	30 (6%)	66 (13.2%)	284 (56.9%)	118 (23.6%)	26 (5.2%)	0 (0%)	0 (0%)	0 (0%)	6 (1.2%)	6 (1.2%)	63 (12.6%)	62 (12.4%)
No	469 (94%)	433 (86.8%)	215 (43.1%)	381 (76.4%)	473 (94.8%)	499 (100%)	499 (100%)	499 (100%)	493 (98.8%)	493 (98.8%)	436 (87.4%)	437 (87.6%)

Visible Sites (N=11):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Questionable	0 (0%)	0 (0%)	2 (18.2%)	7 (63.6%)	9 (81.8%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	6 (54.5%)
No	11 (100%)	11 (100%)	9 (81.8%)	4 (36.4%)	2 (18.2%)	11 (100%)	11 (100%)	11 (100%)	11 (100%)	11 (100%)	11 (100%)	5 (45.5%)

Table 9 Site attribute comparison of all sites vs. visible sites in the Red River counties

Red River Counties: December 20, 1948

All Sites Examined (N=379):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	5 (1.3%)	27 (7.1%)	278 (73.4%)	80 (21.1%)	24 (6.3%)	0 (0%)	0 (0%)	1 (0.3%)	16 (4.2%)	26 (6.9%)	4 (1.1%)	5 (1.3%)
No	374 (98.7%)	352 (92.9%)	101 (26.6%)	299 (78.9%)	355 (93.7%)	379 (100%)	379 (100%)	378 (99.7%)	363 (95.8%)	353 (93.1%)	375 (98.9%)	374 (98.7%)

Visible Sites (N=5):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	0 (0%)	0 (0%)	4 (80%)	2 (40%)	5 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
No	5 (100%)	5 (100%)	1 (20%)	3 (60%)	0 (0%)	5 (100%)	5 (100%)	5 (100%)	5 (100%)	5 (100%)	5 (100%)	5 (100%)

Table 9 (ctd.) Site attribute comparison of all sites vs. visible sites in the Red River counties

Red River Counties: January 6, 1949

All Sites Examined (N=168):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	1 (0.6%)	11 (6.5%)	119 (70.8%)	25 (14.9%)	12 (7.1%)	0 (0%)	0 (0%)	0 (0%)	20 (11.9%)	5 (3%)	4 (2.4%)	10 (6%)
No	167 (99.4%)	157 (93.5%)	49 (29.2%)	143 (85.1%)	156 (92.9%)	168 (100%)	168 (100%)	168 (100%)	148 (88.1%)	163 (97%)	164 (97.6%)	158 (94%)

Visible Sites (N=8):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	1 (12.5%)	0 (0%)	5 (62.5%)	3 (37.5%)	5 (62.5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (12.5%)	1 (12.5%)	4 (50%)
No	7 (87.5%)	8 (100%)	3 (37.5%)	5 (62.5%)	3 (37.5%)	8 (100%)	8 (100%)	8 (100%)	8 (100%)	7 (87.5%)	7 (87.5%)	4 (50%)

Table 9 (ctd.) Site attribute comparison of all sites vs. visible sites in the Red River counties

Red River Counties: November 20, 1949

All Sites Examined (N=509):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	15 (2.9%)	43 (8.4%)	359 (70.5%)	104 (20.4%)	31 (6.1%)	0 (0%)	0 (0%)	1 (0.2%)	31 (6.1%)	67 (13.2%)	5 (1%)	9 (1.8%)
No	494 (97.1%)	466 (91.6%)	150 (29.5%)	405 (79.6%)	478 (93.9%)	509 (100%)	509 (100%)	508 (99.8%)	478 (93.9%)	442 (86.8%)	504 (99%)	500 (98.2%)

Visible Sites (N=4):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	0 (0%)	0 (0%)	4 (100%)	2 (50%)	4 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
No	4 (100%)	4 (100%)	0 (0%)	2 (50%)	0 (0%)	4 (100%)	4 (100%)	4 (100%)	4 (100%)	4 (100%)	4 (100%)	4 (100%)

Table 9 (ctd.) Site attribute comparison of all sites vs. visible sites in the Red River counties

Red River Counties: January-March, 2006

All Sites Examined (N=631):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Question-able	16 (2.5%)	49 (7.8%)	432 (68.5%)	135 (21.4%)	47 (7.4%)	0 (0%)	0 (0%)	3 (0.5%)	47 (7.4%)	69 (10.9%)	7 (1.1%)	16 (2.5%)
No	615 (97.5%)	582 (92.2%)	199 (31.5%)	496 (78.6%)	584 (92.6%)	631 (100%)	631 (100%)	628 (99.5%)	584 (92.6%)	562 (89.1%)	624 (98.9%)	615 (97.5%)

Visible Sites (N=10):

	Unknown Size Surface Scatter	Surface Scatter < 100 sq m	Surface Scatter > 100 sq m	Scatter with Midden	Mounds	Bluff-shelter	Rock Art	Lithic Quarry or Extraction	Artifacts Exposed Only in Test Excavs.	Artifacts Exposed, Restricted Eroded Area	Site Appears on Archival Refs.	Structure Exists on Site
Yes/ Questionable	1 (10%)	0 (0%)	6 (60%)	4 (40%)	10 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (10%)	0 (0%)	1 (10%)
No	9 (99.8%)	10 (100%)	4 (40%)	6 (60%)	0 (0%)	10 (100%)	10 (100%)	10 (100%)	10 (100%)	9 (90%)	10 (100%)	9 (90%)

All of comparisons produced similar results. Sites that are amenable to prospecting are mostly mounds for all of the study areas. Scatters with middens were preferentially represented in the visible sites for Mississippi County and southwest Arkansas, but were absent from the visible sites for Craighead County. Instead, small surface scatters were preferentially represented for the two dates analyzed for Craighead County. In the Red River counties, large scatters tended to deviate only slightly (usually within 10%) from background total. Extant structures were typically associate with visible sites in the January 1949 imagery.

As expected, mounds and historic buildings were the easiest archaeological and historical sites to recognize. This outcome was partially biased by the researcher's familiarity with the anticipated morphologies of those kinds of sites. All of the sites were codified for the presence or absence of mounds in the AMASDA metadata, which encouraged more thorough investigation of the sites listed as "Mounds Present." However, several mound sites were clearly visible without this interpretive aid. Particularly in the 1940s-1950s, farmers tended to avoid mounds either because they wanted preserve them, they were too much trouble to level out and cultivate, or they were using them for other purposes. As such, mounds sometimes appear as clusters of trees that are relatively easy to locate on aerial images of cleared agricultural fields (cf. Vogel 2005:236–237, 257,290–292, 310). Furthermore, the winter months (e.g., November to February) emphasized differential shading of mound sites more clearly than times of the year when crops are grown. Relatively modern structures (e.g., houses, cemeteries) would sometimes be constructed on top of the mounds. This sometimes can aid in the location of known and unknown mounds, but it also can obscure them. The correlation between large mounds and site visibility also is not surprising because land-leveling practices may have completely obliterated near-surface features associated with ancillary activity areas, leaving only partially bulldozed mounds for analysis.

To clarify, historic structures recorded as sites were straightforward to identify, provided that it was known that a building was the object of interest. Some historic structures undoubtedly were misclassified by the researcher in the initial visual assessment because they were mistaken for modern buildings. As such, the counts for historic structures as visible are lower than expected, but they could be corrected with a closer examination of the archaeological site files during classification.

Middens are also amenable to prospecting, but they were less confidently classified. For instance, darker areas on the landscape could represent middens, but they also could represent a natural topographic low, fluvial features obscured by farming, or an area of disturbed soil from a demolished modern feature. Furthermore, mounds commonly have middens present, which would inflate the number of sites classified as visible. Lastly, in comparison to mounds, middens have a limited range of depth. Therefore, some of them may be buried at the time that the images were taken, whereas others may have been land-leveled out of existence. Since the AMASDA metadata are coded for the presence or absence of middens, one could isolate possibly visible sites with middens and compare them with the site records for more confident assessments of visibility.

3. Strategies for Classifying Site Visibility

Similar to Wilson's examples, certain geomorphological features on the landscape can be deceptive to interpretation. Prairie mounds (Figure 10) can complicate interpretations given their mound-like morphologies. Quinn (1961) suggests that prairie mounds in Arkansas were formed through aeolian processes that are impeded by clusters of vegetation in dry areas, causing the sediments to differentially accumulate in these areas. In particular, he characterizes them as having random distributions without overlap, slight asymmetry in cross-section, similar long-axis orientations in groups, and "dimensions normally…between 30 to 60 feet in diameter and from 2 to 4 feet in height" (Quinn 1961:1). These natural features generally are dispersed across landscapes at multiple scales. If a researcher encounters a seemingly round, elevated feature, a good rule of thumb is to observe the image again at a smaller scale. This allows the viewer to determine whether the potential feature is similar to widespread patterns of topographic maxima in surrounding areas, which are more likely to be prairie mounds. The truncation or disturbance of prairie mounds can be useful for interpretation because they can indicate areas of cultural activity (Vogel 2005:228).

Figure 10 Prairie mounds in northeast Miller County

Identifying commonalities in morphology across the image help the researcher determine whether a particular anomaly should be flagged as potentially cultural, and the process of digitizing anomalies helps to reveal homogeneity or patterning in the landscape. For instance, relict stream channels exhibit repeated dendritic patterns, and the curvature of relict meanders can be compared to modern streams (Keifer 1983:519–525; Vogel 2005:224). The primary challenge associated with stream channels is that they can cross-cut features of interest. Furthermore, modern land use can obscure stream patterning and create patches of darker reflectance along relict channels that may look like potential archaeological features. Again, adjusting to a smaller-scale perspective is advisable, and low- to medium-resolution DEMs can provide additional information for these assessments.

Because human modifications of the land leave visible impacts on the landscape in both past and present contexts, disturbances from historic and modern structures can also be confused for past land-use indicators. For instance, historic and relatively modern houses, outbuildings, roads, canals, ponds, etc. are subject to continual construction and demolition. Furthermore, ongoing plowing and land-leveling can obscure more subtle topographic anomalies and physical contrasts in the soil. As a general rule, modern structures generally have crisp edges and sharper contrast with their surroundings in the aerial images. Furthermore, modern features are commonly aligned with respect to the primary cardinal directions, with structures being placed adjacent to and at similar orientations to modern roads. Archaeological features, conversely, are much more subtle and oftentimes have ambiguous edges, particularly in areas subjected to intensive agriculture. Cross-cutting relationships were also useful. For example, modern field system boundaries sometimes cut across anomalies, suggesting that the two are not contemporaneous.

Comparison of orthoimages for each site also increased the researcher’s confidence in visibility assessments. In particular, the direct comparison of higher-resolution images to lower-resolution orthoimages allowed assessments to be made on the latter because certain objects (i.e., trees, buildings) were identifiable in former. The medium-quality downloads from EarthExplorer were otherwise difficult to interpret. Adjusting contrast settings for each orthoimage in ArcGIS was useful, particularly when an anomaly appeared on one image but is not immediately apparent on another image. Furthermore, viewing archaeological sites at multiple scales revealed other anomalies in proximity to the site locations that could be archaeological or geomorphological. These, in turn, could be further investigated. However, ground-truthing or otherwise investigating these unknown anomalies in the field is beyond the purview of this study.

B. INTRASITE ANALYSIS

1. Assessment of DEM Generation Performance

The geometry-building algorithms performed well overall, but the resultant DEMs are not without error. For instance, stereoscopic DEMs are sensitive to differences in vegetation height. Unless differences in tree height closely follow underlying topographic conditions, forest canopies have an obscuring effect. Topographic errors appear to be most pronounced in areas of dense vegetation and tree coverage because they produce long, dark shadows, which are incorporated into the resultant geometry and exaggerate differences in lighting between the adjacent aerial images. Furthermore, geometric errors also tend to occur on the edges of the model, where the point model is less constrained by surrounding GCPs. However, considering the amount of time required to conduct a high-resolution topography survey, this provides a fast preliminary approximation of historic topography.

For both large (i.e. countywide) and small regions (i.e. individual agricultural fields), the algorithms were best at distinguishing roads, canals, and large river channels. The former two could, in part, be related to the fact that bridges and crossroads were preferentially selected as GCPs. These features also tended to exhibit greater homogeneity of reflectance values, which could have improved the software's height approximations.

Although such high-resolution specifications slow processing time considerably when more than a few images are used, the program can process small regions of <10 km^2 in a matter of minutes. One might expect that an increase the number of images used in the geometric solution would increase the accuracy of the topographic model. However, for the areas studied, single stereopairs consisting of two images—one taken directly after the other from the same transect—seemed to provide the best results in terms of resultant DEMs and processing times. This makes intuitive sense because of the manner in which the airplanes collected the images. For an alternating flight transect pattern, images taken immediately in sequence would have the most overlap and very similar conditions of photograph capture (e.g., natural lighting angle, mean reflectance values across the image), whereas photographs taken on the next pass would have slightly different conditions. Although PhotoScan generates aerial mosaics without considerable trouble, DEMs derived from multiple flight transects sometimes produce seams between images, a source of noise that can obscure intrasite features. Furthermore, they take far longer to process for a predefined region than for a stereopair.

2. Strategies for Interpreting Specific Sites

Each site chosen for intrasite analysis was thoroughly digitized to distinguish geomorphological anomalies from cultural anomalies, and modern cultural anomalies from past cultural anomalies. When conducting the general site visibility assessment over hundreds of archaeological sites or prospecting within a new region, certain anomalies will be identifiable based on previously described characteristics (e.g., color, shape). The locations of such anomalies should be noted, and a brief comment should be included to indicate why that particular anomaly was flagged for follow-up analysis. For example, in ArcGIS, this can be done by creating a shapefile and appending comments to the attribute table. These anomalies will help the researcher determine the bounding box for the high-resolution DEM and orthoimage. The DEM then can be cropped and custom hillshades can be created to aid in interpretation.

During intrasite analysis, anomalies present on the orthoimages can be sorted into several generalized categories on the basis of shared properties such as "light anomalies," "dark anomalies," and "anomalies with differential shading." These can be further subdivided according characteristics specific to certain anomalies such as "light anomalies with dark outlines." Provided that the area is sufficiently small (e.g., <500 hectares), anomalies can be digitized intensively, providing an initial assessment of the patterning associated with each type. Modern anomalies—roads, houses, streams, canals—should be digitized as well because they assist in assessments regarding association of unknown anomalies to their surroundings.

Even with high-resolution imagery, the geometry of past and present features can be challenging to interpret, making the historical DEMs vital resources. In particular, PhotoScan-generated DEMs effectively model linear grooves and ridges. This makes them particularly useful for digitizing not only roads, canals, and field boundaries, but also past and present stream systems. For the latter, modern land can redirect natural streams, creating counterintuitive stream configurations that are sometimes difficult to interpret, and the historical DEMs allow for the digitization of streams with greater confidence. Although tree coverage is problematic and the model can introduce erroneous artifacts, the models also highlight high and low regions with reasonable accuracy, and they can be compared with modern downloadable DEMs as an additional comparative measure. Thus, unknown anomalies can be compared with local topography by switching back and forth between the orthoimages and the DEMs.

For example, patches of dark anomalies sometimes correspond with relict stream channels, and they subsequently can be assigned as being of geomorphological origin. Particularly when digitizing stream channels, one must constantly adjust the viewing scale to get a sense of how the anomaly fits into the larger geomorphological context. Oftentimes, relict meandering streams and oxbow lakes appear as dark or vegetated areas that are broken by modern land modification, but are recognizable with remarkable clarity when zoomed out to a larger viewing extent. Furthermore, paths and drainages that run parallel to each other sometimes intersect and form square geometric patterns that can be mistaken for cultural anomalies. This kind of misinterpretation can be avoided by digitizing linear features apparent in the orthoimagery and DEMs. As another example, some circular anomalies hypothesized as mounds on the orthoimagery can in fact represent topographic lows, and the DEMs usually have sufficient accuracy to correct these initial interpretive errors.

3. Proposed Site Features

Although the aerial images have limited applications for extensive site prospecting of unknown sites, they brilliantly capture historical landscapes around known mound sites, and anomalies adjacent to mound sites encourage the reinvestigation of these areas to determine whether any of these proposed features are archaeological. In turn, this provides exciting new avenues for future surveys and excavations. The delineation of site boundaries is constrained by several key factors such as: federal project boundaries, access to areas by private landowners, time and budget constraints for surveying, and the present-day surface residues of archaeological sites. Therefore, aerial images provide a non-invasive means for reevaluating site boundaries and locating possible archaeological features that went unrecorded in earlier investigations and that may now be destroyed.

Systematic classification of archaeological features versus modern and natural features is still a work in progress, and it will require further investigations to identify features with certainty. The archaeological sites presented here were chosen (1) to present promising anomalies for future investigation and/or (2) to demonstrate the successes and shortcomings of the site-specific geometric models. The reasoning for assigning cultural rather than natural origins to these anomalies is provided, as well as particular challenges to interpretation on a case-by-case basis. Digitized anomalies are presented, but specific geographic information is intentionally excluded from the descriptions in an attempt to preserve the integrity of the sites.

At this stage, these interpretations are proposals for possible features, which will need to be corroborated with other forms of evidence (e.g., additional aerial coverage, surface surveys, geophysics, excavation). Some of the proposals undoubtedly will be incorrect, but these proposals are a necessary step towards creating an historical aerial imagery database with an index of recognizable archaeological site and feature types.

a. Craighead County Sites

i. Old Town Ridge (3CG41)

The Old Town Ridge Site (3CG41) in northeast Craighead County is a Middle Mississippian site with a rectangular enclosure and paleochannel that are highly visible in aerial imagery. Lockhart, Morrow, and McGaha (2011) present the results of magnetic gradiometry surveys over parts of the enclosure to look for internal archaeological features, revealing potential structures as well as linear liquefaction features ("sand blows") caused by earthquakes.

Although material evidence suggests thousands of years of occupation in the vicinity of Old Town Ridge, use of the enclosure has been dated to a relatively short temporal context circa AD 1275-1425 (Lockhart et al. 2011:56). In this respect, it is similar to the Spinach Patch site (3FR1), a "single phase" site in Franklin County, Arkansas, which appeared well in the Ozark Reservoir Papers' imagery (Hoffman et al. 1977:117). If anomalies from occupation are apparent at all on the surface—i.e. have not been buried or completely removed—sites of short occupational histories with substantial disturbance or modification of the soil will be the easiest to interpret.

EarthExplorer coverage was limited to medium-resolution downloads from May 18, 1956, and January 17, 1976 (Table 10). Medium-resolution aerial downloads are generally dismissed as unviable for archaeological prospecting. However, the latter was of sufficiently large scale (1:15,000) for archaeological interpretation. Furthermore, in comparison to the 1976 and 2006 images, the 1956 imagery was particularly useful for delineating streams and relict channels.

Table 10 PhotoScan orthoimage and DEM coverage for Old Town Ridge (3CG41)

Agency	Acquisition Date	Scale	Download Resolution	DEM Generated
Army Map Service	05/18/1956	30,000	Medium	No
USGS	01/17/1976	15,000	Medium	Yes

Orthoimages for the Old Town Ridge Site were difficult to interpret because the 1976 and 2006 images exhibited highly patchy appearances with relict channels creating areas of high tonal contrast. As such, particular anomalies were isolated on the basis of morphological types, but are by no means an exhaustive representation. Although the 1976 DEM is more detailed than the 2006 DEM, the former also exhibits more noise. The orthoimages and DEMs for 1976 (Figure 11) and 2006 (Figure 12) clearly delineate areas with trees, as well as modern roads, field boundaries, canals, and standing structures. Both depict relict paleochannels as topographic lows, and they place the enclosure on an elevated area in the south-central part of each map.

Orthoimagery and DEM (1976), Outside of the enclosure: Four circular to elliptical anomalies (Figure 11, teal) have darker tones on their northwest sides, indicating possible topographic relief. Mounds are associated with this site, but these anomalies are all either within or aligned with the side of the main relict channel, suggesting that they may be natural landforms. Furthermore, the 1976 DEM places the two eastern anomalies of this type in topographically low areas, and the other two do not have topographic expressions. Dark anomalies (Figure 11, pink) are present within the paleochannel, which are attributed to patches of differential drainage. Three other dark anomalies in the southwest (Figure 11, yellow-orange) correspond with a linear anomaly interpreted as a small stream channel on both the 1976 and 2006 images (Figures 11-12, blue). Two roughly circular, light anomalies in the northeast part of the map (Figure 11, white), could represent soil displacement from past cultural activities, producing an areas of differential drainage and/or vegetation.

In comparison to the interpretations from the orthoimage, only the modern roads, field boundaries, canals, and standing structures have clear topographic signatures in the 1976 DEM. The 1976 DEM presents some small elevated areas (Figure 11, magenta) that did not correspond with modern buildings or trees. Most of these anomalies occurred in a topographically high region with variable terrain in the north-central part of the viewing area. Although these could be errors in the geometric model, the DEM precisely modeled buildings and trees in the 1976 image of roughly the same x and y dimensions. This suggests that these potentially elevated areas are worth examining.

Orthoimagery and DEM (2006), Outside of the enclosure: Aside from the relict streams, roads, canals, buildings, vegetated areas, and anomalies near the enclosure, anomalies isolated in the 2006 image and DEM corresponded little with that of 1976. Dark anomalies were observed within the paleochannel (Figure 12, pink) that were similar to those seen in 1976, further indicating that anomalies of this type are of fluvial origin. Small dark anomalies (Figure 12, yellow-orange) were observed to the south and east of the enclosure, which are roughly consistent with the size of structures hypothesized within the enclosure. Other, larger ones were observed in the northeast part of the viewing area, but they are part of a larger pattern within that field and are assumed to be natural features. The light circular anomaly in the north-central field (Figure 12, white) is too large to be a residential structure, but could be an elevated cultural activity area. Lastly, a darker region (Figure 12, brown) to the north of the main paleochannel has an unusual shape, but likely represents parts of relict streams, the southernmost edge corresponding with the main channel.

Orthoimagery and DEM (1976 and 2006), Within the enclosure: The boundaries of the enclosure are clearly delineated in the 1976 and 2006 orthoimages (Figure 13, black). The enclosure does not have a distinct topographic signature in the 1976 DEM, but it corresponds with a slightly elevated area in the 2006 DEM. For both images, a northwest-trending dark linear anomaly within the enclosure (Figure 13, pale green) directly corresponds with a magnetic anomaly interpreted as a sand blow (Lockhart et al. 2011:56). Two anomalies to 100m and 175m to the east run parallel to it and have similar morphologies, suggesting that these may be sandblows, as well. In the 2006 image (and the 1976 image to a lesser extent), a dark anomaly

(Figure 13, dark purple) to the east of the posited sandblow matches a square magnetic anomaly presented in 2011 (Figure 13, red), and this corresponds with a slight topographic high in the 2006 DEM (Figure 13, magenta). Other dark anomalies in the north part of the enclosure (Figure 13, dark purple) are of the right dimensions and shape to be structures, excluding the larger circular anomalies in 1976 and 2006. The dark anomalies in the northeast part of the enclosure lie within a dark linear anomaly, so they again could be associated with another sandblow or a past drainage feature. Another dark, linear anomaly (Figure 13, dark purple) visible in both images is oriented parallel to the northeast corner of the enclosure, which could represent an earlier stage of the enclosure's construction. A wider linear anomaly runs parallel to the southern border of the enclosure (Figure 13, dark purple), and it was previously hypothesized as a former boundary for the enclosure prior to expansion. In the 1976 image, a light circular anomaly (Figure 13, yellow) to the west of the interpreted sandblow is located on a topographically elevated area according to the 2006 DEM. Although it does not show up on the 1976 DEM, the change in reflectance could be attributed to differential drainage, artificial accumulation of soil to elevate that area, and/or a difference in vegetation. This anomaly also corresponds with a magnetically variable part of the magnetometry survey.

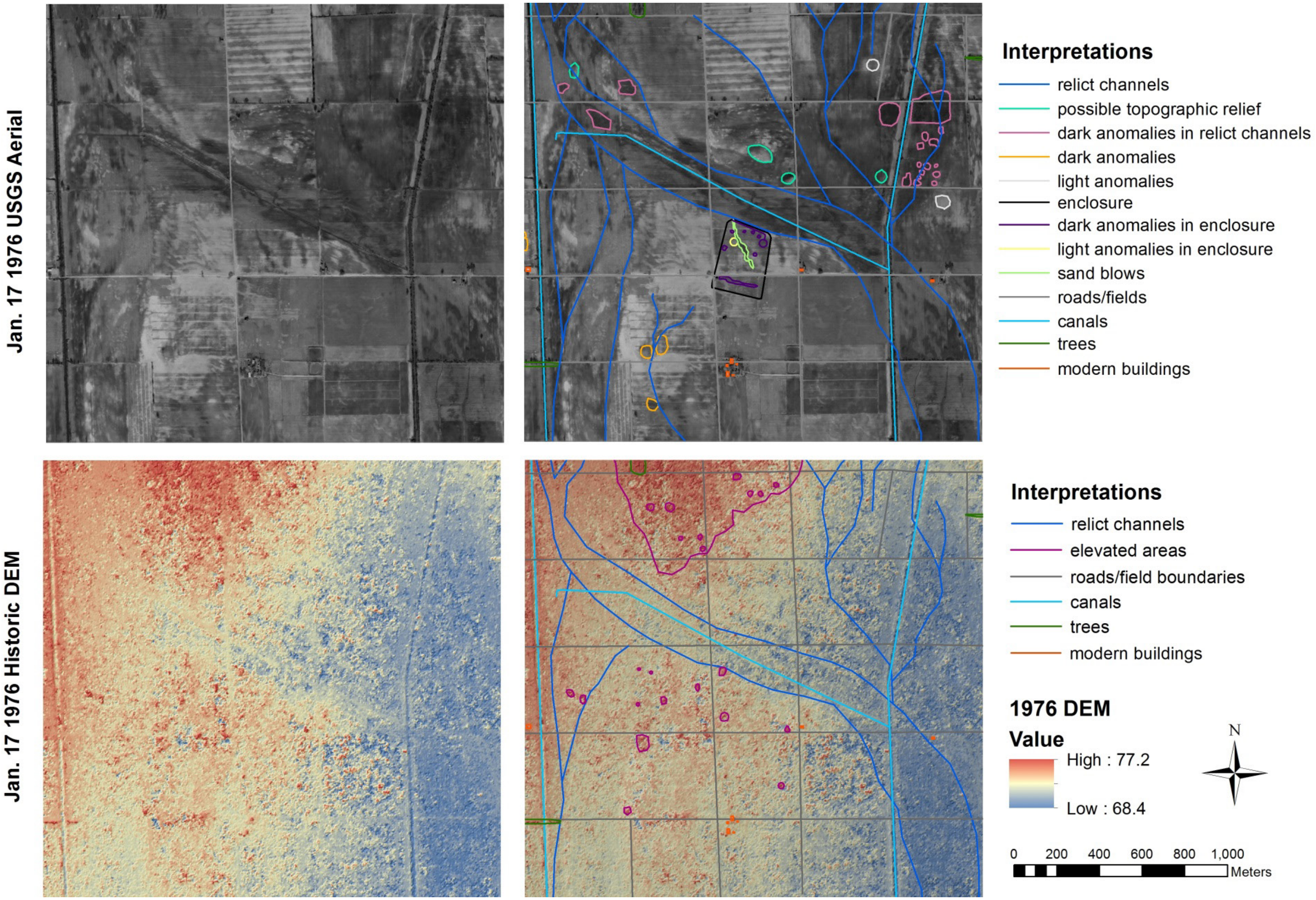


Figure 11 Old Town Ridge Site (3CG41) interpretations of a PhotoScan-generated historical orthoimage and DEM (Jan. 17, 1976)

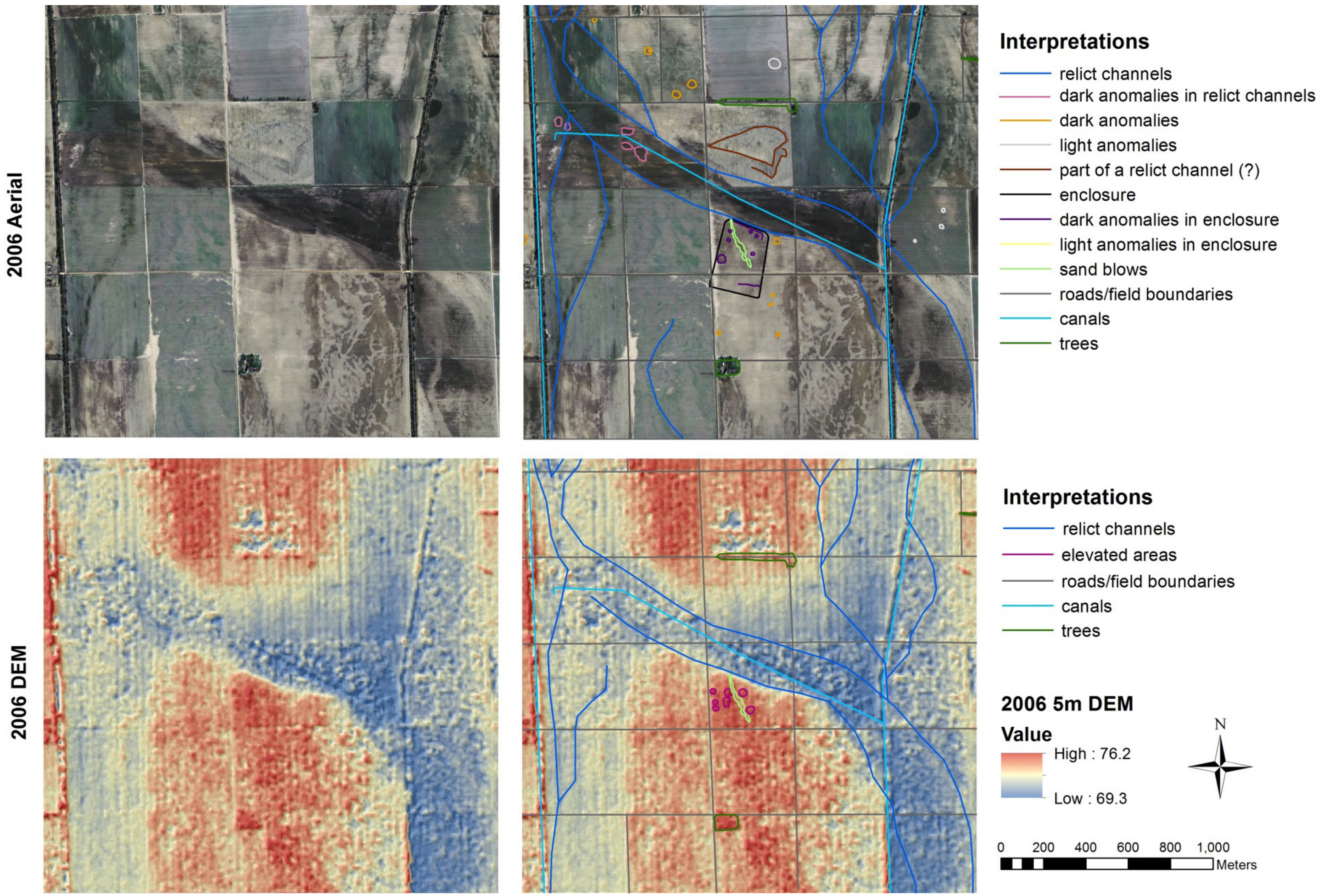


Figure 12 Old Town Ridge Site (3CG41) interpretations of the Arkansas State Land Information Board orthoimagery and 5m DEM (Jan. 15-Mar. 31, 2006)

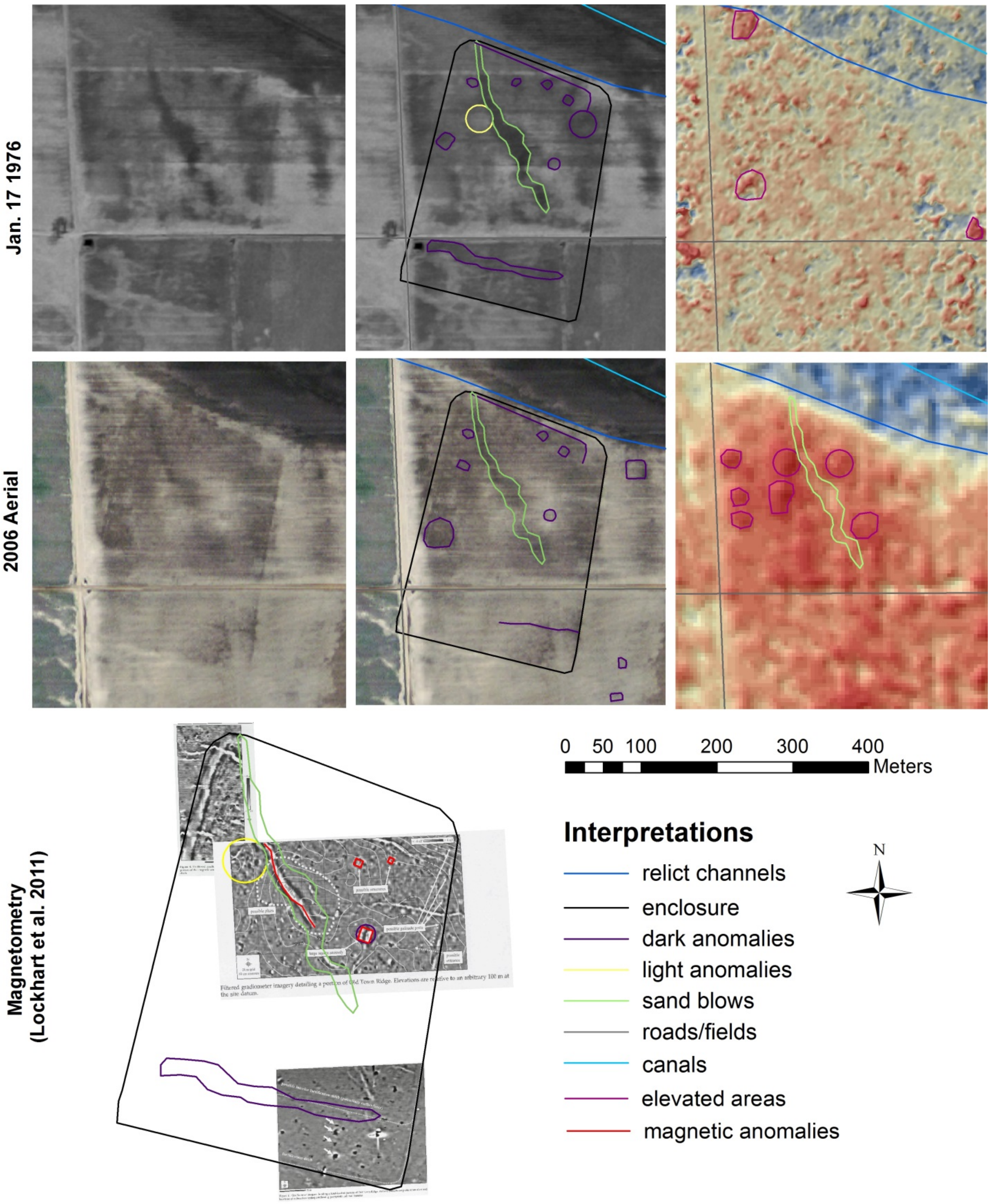


Figure 13 Close-up view of the enclosure from the Old Town Ridge Site (3CG41) with magnetic gradiometry data for comparison (after Lockhart, Morrow, and McGaha 2011, with permission).

ii. Armstrong Site (3CG64)

The Armstrong Site (3CG64) is a Middle Mississippian village in southeast Craighead County that is composed of temple and house mounds. A 1968 site survey reported "three or four temple mounds. [sic] and 5 or 6 house mounds" (AAS Site Survey Files). During this investigation, Dan Morse produced a sketch map of the mounds labeled A-I within the site, and the map was redrawn in 1988 (Figure 14).

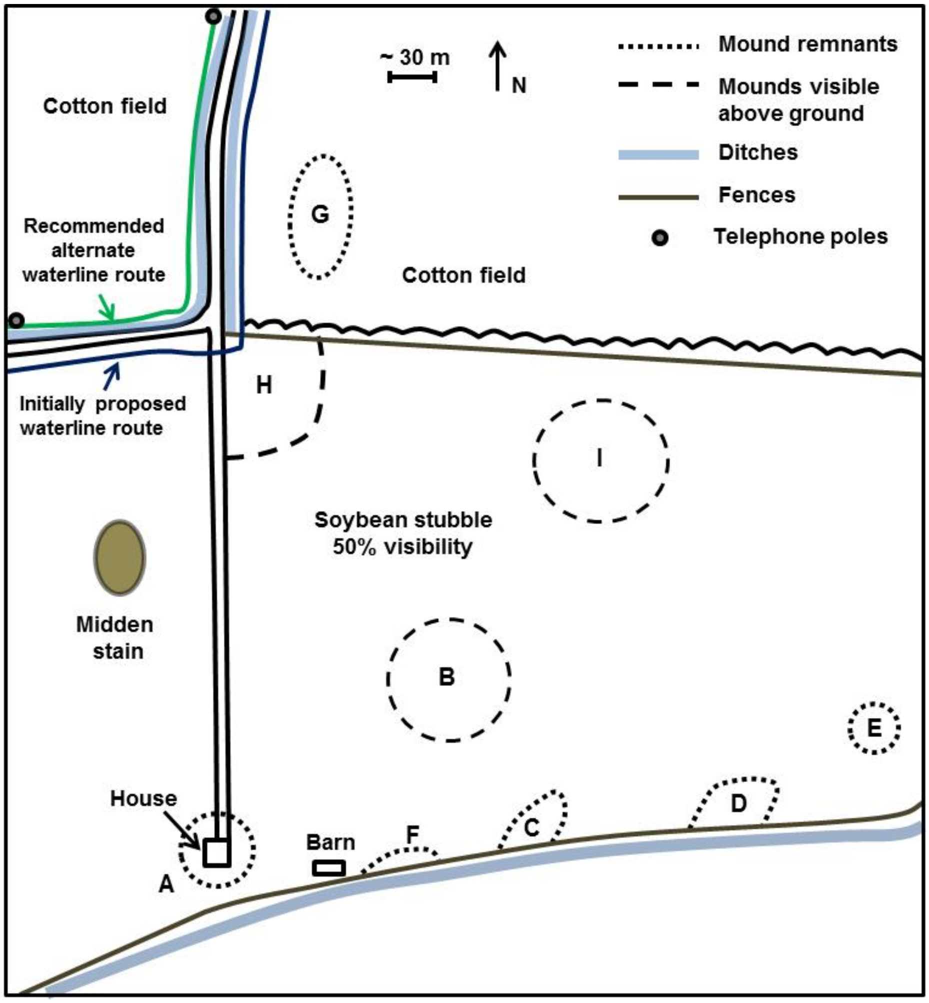


Figure 14 A sketch of the Armstrong Site with mounds placed according to Morse's 1968 sketch (after Hinkle 1988, AAS Site Survey Files). Mounds B, H, and I were identified as temple mounds; A, C, D, E, and F as house mounds; and G as a natural ridge that could be a mound.

According to the AAS Site Survey files, surface collections in 1988 revealed flakes, debitage, Mississippian sherds, and historic sherds. Collections of Mounds A-D in 1989 revealed primarily Mississippian and 18th to 20th Century sherds, but a few Archaic projectile points were found, as well. The site had been subject to looting, and preservation of the mounds was hindered by road construction, land-leveling, and displacement of mound soils for modern use. As of 1988, Mounds H, I, and B still exhibited visible surface topography whereas A, C, D, E, and G were only partially preserved (AAS Site Survey Files). By 1992, Morse observed that Mound G had been completely destroyed and that Mound H had been reduced by approximately one foot (AAS Site Survey Files).

Aerial coverage for this site was limited to medium-quality downloads from January 17, 1976, but the scale (1:15,000) was adequate for interpretation (Table 11).

Table 11 PhotoScan orthoimage and DEM coverage for the Armstrong Site (3CG64)

Agency	Acquisition Date	Scale	Download Resolution	DEM Generated
USGS	01/17/1976	15,000	Medium	Yes

Orthoimagery and DEM (1976): The house (Figure 15-16, yellow) on top of Mound A (Figure 15-16, red) obscures it in the 1976 and 2006 imagery, and it appears as an artificial high in the DEMs due to the presence of the standing structure. The largest “temple” mounds (i.e. Mounds B, H, and I) correspond with lighter, roughly circular zones in the 1976 imagery. The predominance of sandy soils at the site (AAS Site Survey Files) would drain well and produce these kinds of contrasts. Mounds H and I (Figure 15, red) have subtle shading on their northern sides, further indicating topographic relief. Mound B (Figure 15, purple) has a dark center surrounded by a lighter halo, which could be attributed to the removal of soil from Mound B to be “used as [a] foundation for [the] carport of [the] house on Mound A,” reported in 1968 (AAS

Site Survey Files). In the 1976 DEM, Mounds H and I (Figure 15, maroon) appear as elevated areas with discernible boundaries, whereas Mound B appears as a cluster of small elevated areas. The latter observation further supports the displacement of the upper mound layers for modern construction.

To the east of these three mounds, two prominent light-colored anomalies (Figure 15, purple) were initially identified as mounds because they had sizes and shapes similar to the documented mounds. However, the larger of the two is consistent in tone to the interstitial area between Mounds B, H, and I, which could be some sort of central plaza. If so, that area could be extended to include this anomaly with a northeast-trending relict stream dividing the two parts. The other light anomaly corresponds with the placement of Mound D in sketches from mapping conducted in 1989 (AAS Site Survey Files). It has no topographic expression in the 1976 DEM, which is consistent with sketches from the 1988 and 1989 site records. Mounds F, C, and E (Figure 14) were not apparent on the available orthoimagery and DEMs. Another light, square anomaly (Figure 15, purple) is immediately north of Mound A and is oriented 45 degrees from north. This anomaly roughly aligns with Mound G and has a dark anomaly on top of it (Figure 15, brown). However, it is bounded on its northeast and southwest sides by linear features interpreted as paths, which may create the false impression that it is square.

A series of paths (Figure 15, thin black lines) interpreted from the 1976 hillshade model run perpendicular to the dark linear anomalies interpreted as stream channels. A few clusters of dark anomalies (Figure 15, brown) are also present, but they tend to align with posited paths or drainages. Therefore, they more likely are localized areas with different drainage properties rather than indicators of past structures. Other dark anomalies (Figure 15, brown) in the north-central part of the viewing area could be of archaeological significance. These include (1) a northeast-trending rectangle of approximately 100m x 40m, (2) a small square approximately 15m on the side, and (3) three small circles approximately 5m in diameter. The first could be some sort of bounded activity space such as a field, whereas the smaller anomalies could be related to past structures. These anomalies are outside of previously investigated areas and require further analysis to be substantiated.

Orthoimagery and DEM (2006): In 2006, Mounds H, I, and B appear as darker areas of reflectance surrounded by lighter halos (Figure 16, red), with Mounds H and I transitioning back to a lighter reflectance in the center. Mounds I and B are topographically elevated in the 2006 DEM, but the edges of Mound B are not visible. Mound H has been almost completely land-leveled. Two other topographic highs appear in the same field (Figure 16, maroon) with drainages going around them. The easternmost one encompasses a slightly depressed drainage area, and the other aligns with a slight topographic high in the 1976 DEM. As elevated areas with reduced erosion in an area prone to flooding, these anomalies may have been preferred for certain activities, or they may exhibit better preservation of material culture.

Two large, dark anomalies (Figure 16, brown) are present in the north-central field, one of which directly corresponds with the light square anomaly in the 1976 orthoimage (Figure 15, purple). The other dark anomaly overlaps an apparent relict stream, but is approximately square, suggesting that it could be a cultural feature. A few smaller dark anomalies (Figure 16, brown), dark-outlined anomalies (Figure 16, dark blue-green), and light anomalies (Figure 16, purple) are also present. The former two categories correspond with topographic lows on the 2006 DEM, and they are probably are related to natural drainage patterns.

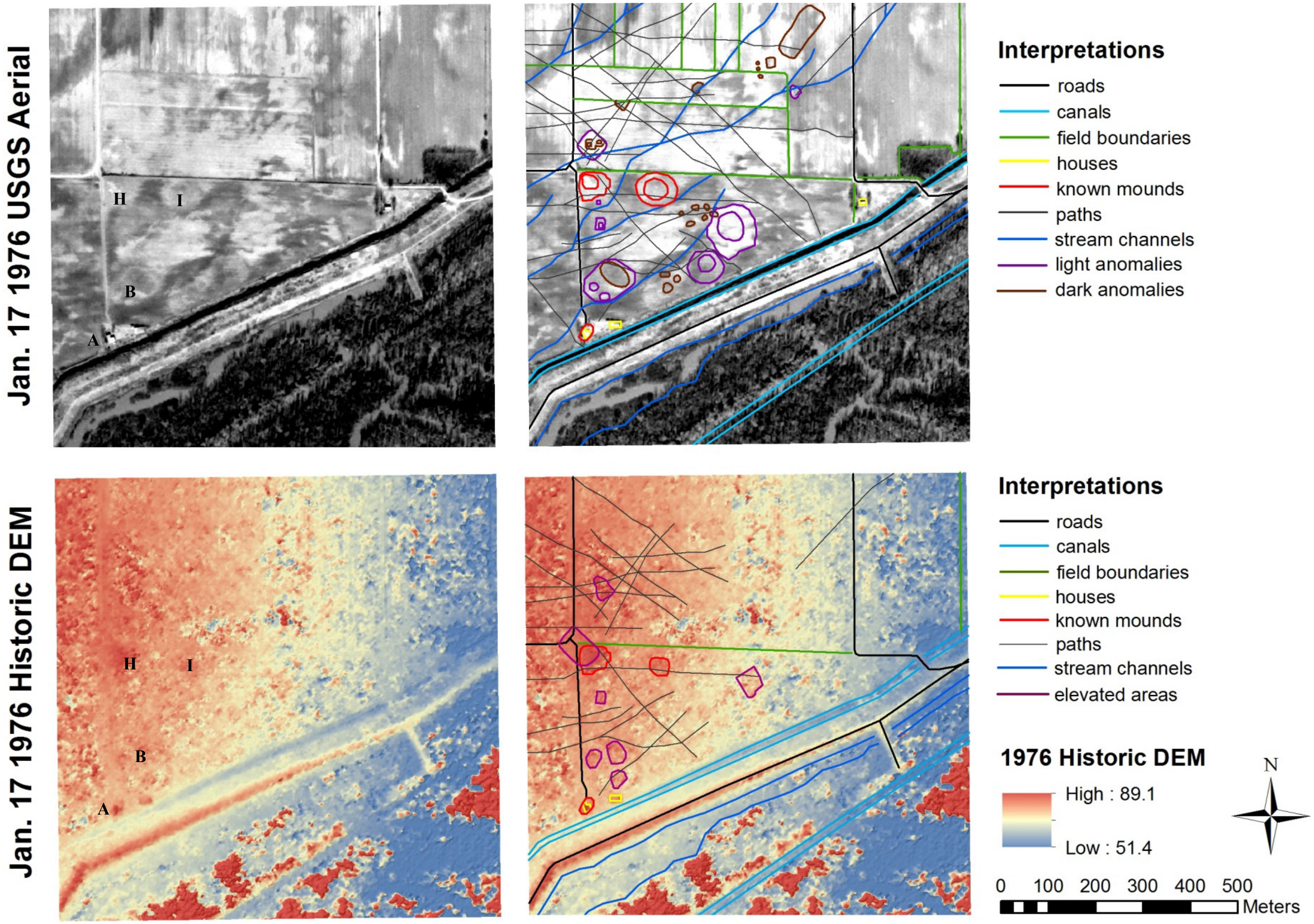


Figure 15 Armstrong Site (3CG64) interpretations of a PhotoScan-generated historical orthoimage and DEM (Jan. 17, 1976).

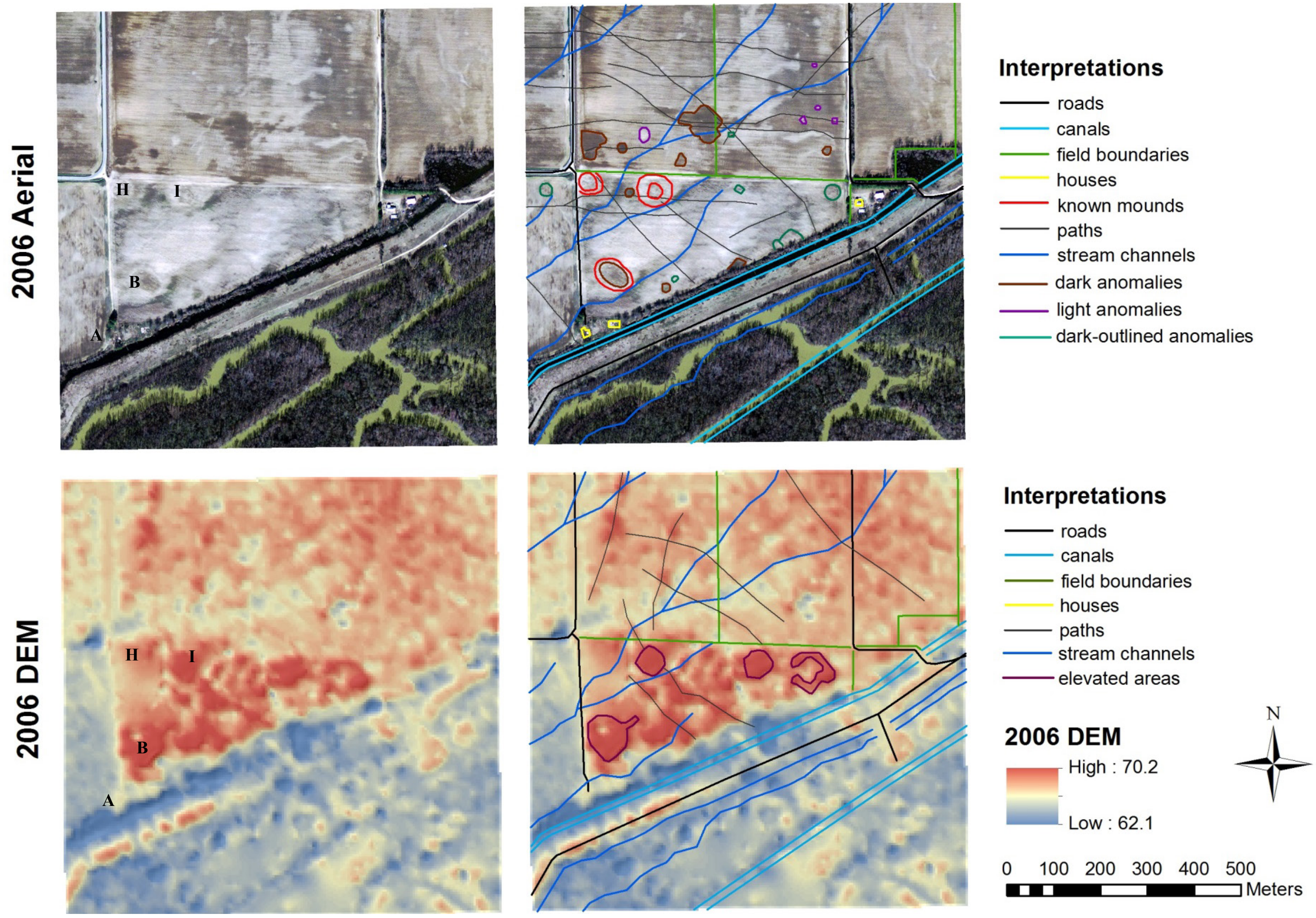


Figure 16 Armstrong Site (3CG64) interpretations of the Arkansas State Land Information Board orthoimagery and 5m DEM (Jan. 15-Mar. 31, 2006)

iii. 3CG991

3CG991 is located in the southwest corner of Craighead County. It was reported in 1990 as a single-mound Woodland to Mississippian site which produced a few grog- and sand-tempered sherds and 19 flakes during surface collections (AAS Site Survey Files). Systematic shovel tests were conducted in 2011 prior to complete land-leveling of the mound. The plowzone was completely removed, revealing no identifiable features or structures apart from an 80 cm deep pit at the top of the mound. This pit was originally thought to be a grave, but no human remains were uncovered (AAS Site Survey Files). The shovel test pits designated the mound as a natural landform that was used at least in passing by past peoples. The site report associated with the 2011 work is in progress.

Although this is not a major archaeological site in Craighead County, patterns apparent in the available aerial imagery (Table 12) may encourage revisitation of peripheral areas around the mound. Large-scale (1:23,000) and high-resolution downloads are available for February 2, 1964. Partial coverage of the site is also available for January 9, 1975. Although the 1975 imagery does not have high-resolution downloads available at this time, it is of sufficiently large scale (1:15,000) for analysis. The main downside of the latter dataset is that it does not cover the southwest anomalies revealed in 1964, and it has even less of an overlap region for 3D modeling.

Table 12 PhotoScan orthoimage and DEM coverage for 3CG991

Agency	Acquisition Date	Scale	Download Resolution	DEM Generated
USGS	02/02/1964	23,000	High	Yes
USGS	01/09/1975	15,000	Medium	Yes (Partial Coverage)

The area selected for analysis is largely dominated by relict meandering streams, some of which have subsequently been converted to present-day canals. The mound 3CG991 was completely covered in trees in 1964 and 1975, and it is not visible in the orthoimages and DEMs for those years (Figures 17-18). In general, the 1964 DEM had some unusual north-south-trending striping patterns and problems with seams between images (Figure 17, dashed line). Additional GCPs were added, but this did not resolve this issue. As a result, certain topographic anomalies are detected in the model, but they are obscured by artificially elevated and depressed regions. Pre-processing of these images may improve the model's performance. Unlike models produced for other archaeological sites, the 1964 DEM was less sensitive to tree coverage and only modeled patches of trees (Figure 17, green), which could represent areas of more dense vegetation growth. The 1975 DEM had a smoother appearance with minor seams (Figure 18, dashed line); however, the areas of overlap required for the 3D modeling were limited.

Adjacent cleared fields to the north and west revealed a series of approximately circular anomalies that show up as areas of lighter reflectance (Figures 17-19, tan). These are apparent in the 1964 and 1975 imagery, and less so in the 2006 image. The repeated pattern of the circular anomalies suggests that they are prairie mounds. These areas dominated by possible prairie mounds were modeled as topographically variable in a similar manner to the 1964 DEM. However, some of the larger ones exhibit topographic relief on the DEMs (Figures 17-19, magenta), and the most prominent anomalies align with a channelized stream (Figures 17-19, dark blue). This could indicate that they underwent less land-leveling than the central portions of the agricultural fields. However, some of these possible prairie mounds have comparable morphologies to mound 3CG991 in terms of size, shape, shading, and coloration on the orthoimages (Figures 17-19, purple). In turn, they could have been associated with past cultural activities in the same manner as the known mound, even if these landforms originally were of natural origin. Dark anomalies (Figures 17-19, orange) were also scattered across the viewing area. The ones not directly associated with the prairie mounds were aligned with present and past stream channels. A dark, rectangular anomaly present on one of the easternmost prairie mounds in 1964 (Figure 17, orange within yellow) could represent a structural foundation.

Another rounded-square anomaly covered in trees is present on the west-central side of the selected area (Figures 17-19, yellow). Its morphology is very similar to mound sites found elsewhere in Arkansas, but it is the Denton Island Cemetery. The known graves from this cemetery date to the early 20th Century, and it is not listed as an archaeological site in the AMASDA database. However, it could represent an historic cemetery placed on a manmade mound or a large prairie mound, which is not uncommon. Whether that particular elevated area was of cultural significance prior to its use as a cemetery could be corroborated with surveys of the adjacent fields.

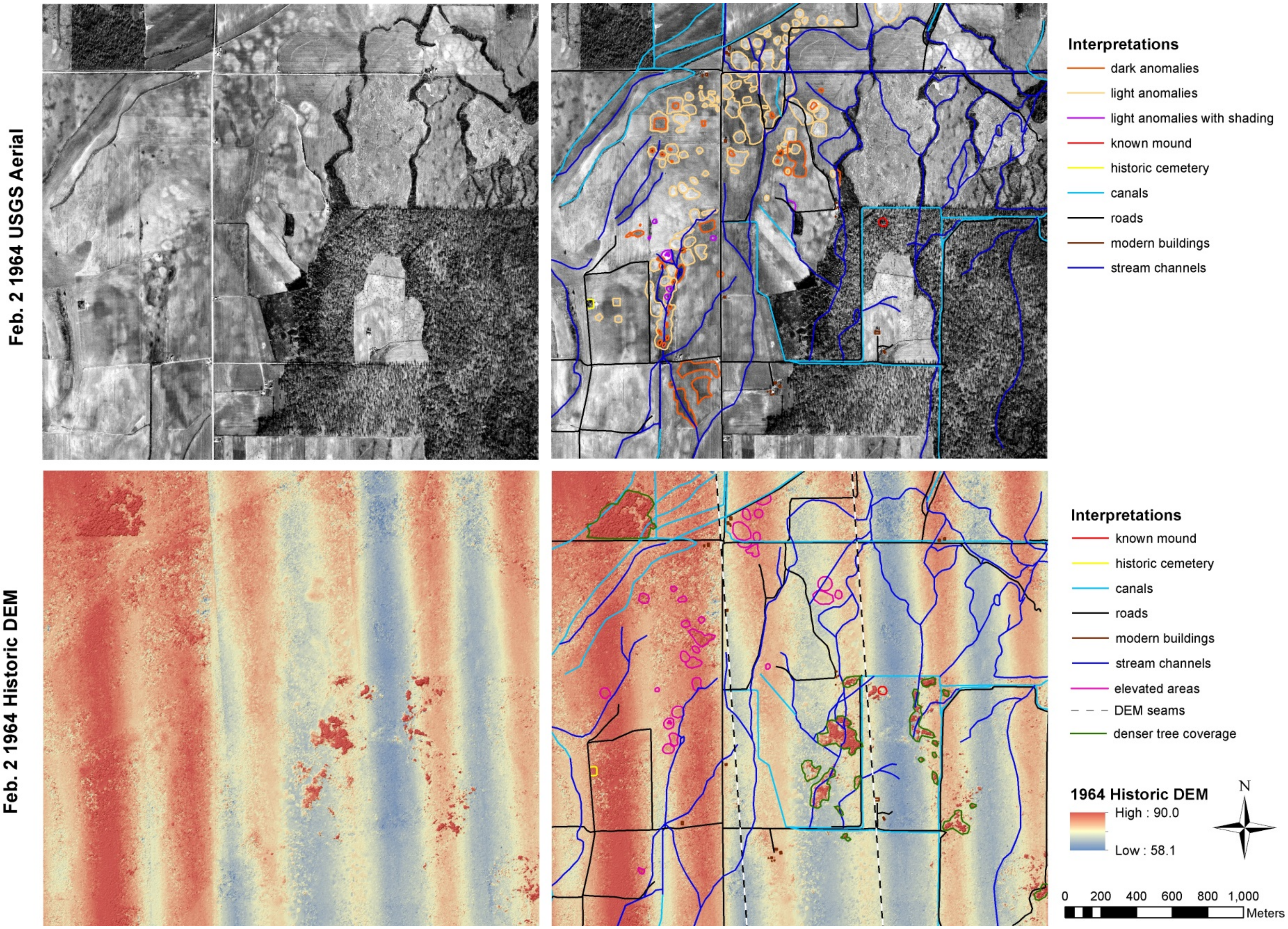


Figure 17 3CG991 interpretations of a PhotoScan-generated historical orthoimage and DEM (Feb. 2, 1964)

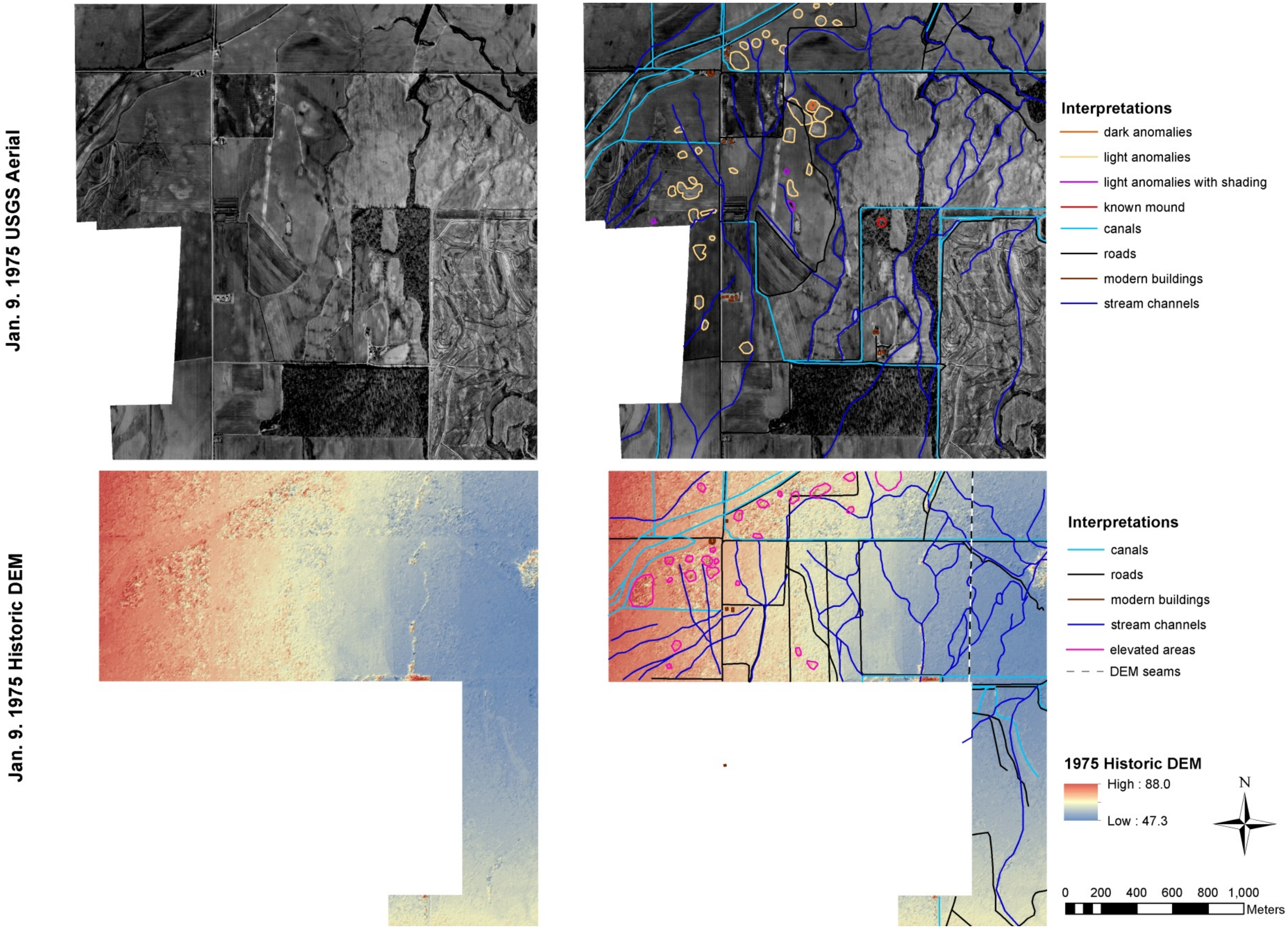


Figure 18 3CG991 interpretations of a PhotoScan-generated historical orthoimage and DEM (Jan. 9, 1975)

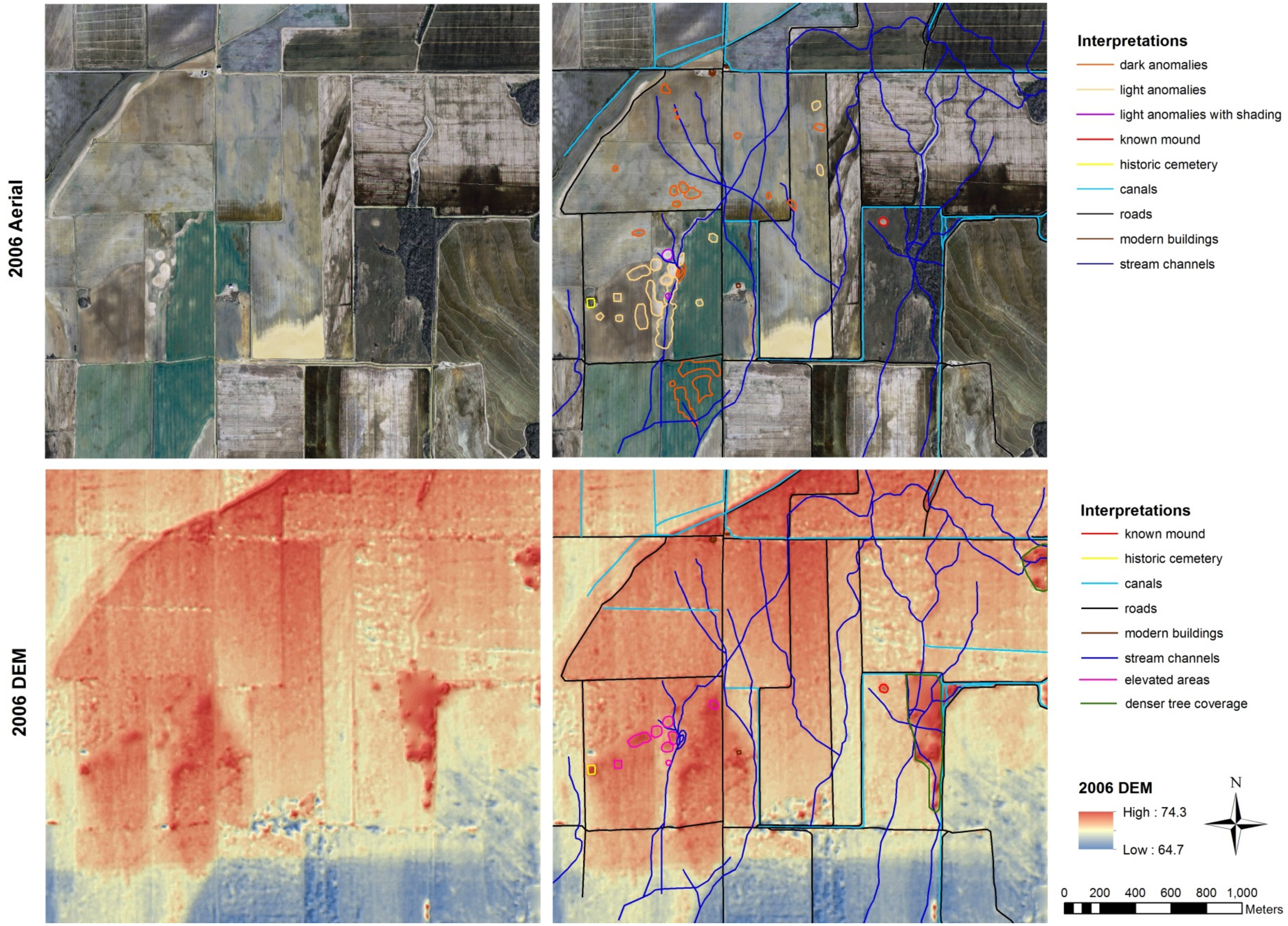


Figure 19 3CG991 interpretations of the Arkansas State Land Information Board orthoimagery and 5m DEM (Jan. 15-Mar. 31, 2006)

b. Mississippi County Sites

i. Sherman Mound (3MS16)

Sherman Mound (3MS16) is an Early to Middle Mississippian site along the Mississippi River, featuring a three-tiered mound. An historic manuscript on file at the Arkansas Archaeological Survey briefly summarizes personal visits to the mound in 1897 to 1900, 1930, 1933, and 1945. Primarily, burials were found adjacent to the mound from the construction of the railroad to the west and the removal of soil to be used as fill (AAS Site Survey Files). Investigations in1966 proposed that a peripheral village area was located within the same agricultural field (AAS Site Survey Files). In response to a proposed transmission line corridor, the site was mapped in 2001, revealing three artifact concentrations (A, B, and C) and two apparent topographic ridges that could represent mounds (Figure 20).

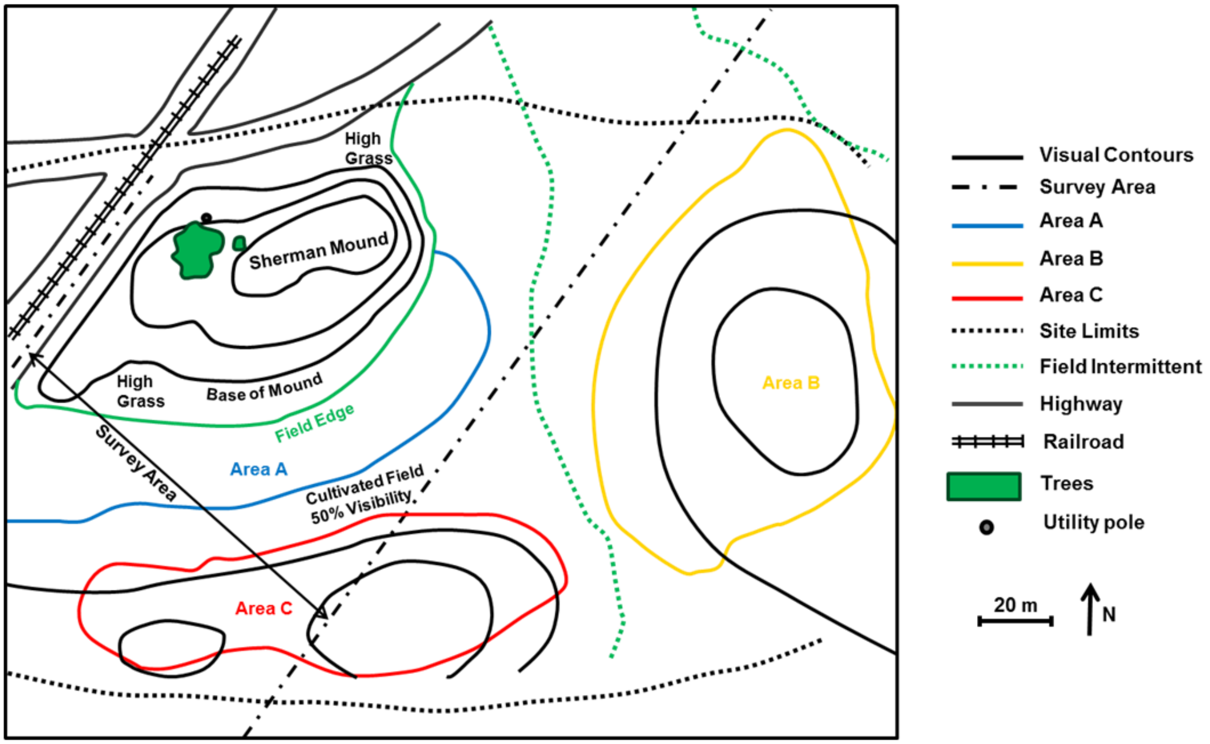


Figure 20 Sketch of 2001 survey of Sherman Mound (after Latham et al. 2001, AAS Site Survey Files). Surface concentrations were observed in Areas A (blue), B (yellow), and C (red).

Although relatively large-scale medium-quality downloads were available for January 1976, the April 1971 orthoimagery and DEM were selected for analysis (Table 13).

Table 13 PhotoScan orthoimage and DEM coverage for Sherman Mound (3MS16)

Agency	Acquisition Date	Scale	Download Resolution	DEM Generated
USGS	04/07/1971	21,200	High	Yes
USGS	01/17/1976	15,000	Medium	No

Sherman Mound was selected for follow-up analysis because it features a set of similarly sized anomalies that appear to be arranged in a circular fashion to the east of the main mound (Figure 21- 22, red) in the high-resolution orthoimage dating to April 7, 1971 (Figure 21, light green). These anomalies were isolated on the basis of their morphologies, size, and configuration. Namely, they all appear to be approximately circular or rectangular with rounded edges and 20 m to 30 m in diameter. With respect to the larger known mound, they form an ellipse configuration with the long axis oriented roughly east-west. Each of these anomalies consists of an inner area of higher reflectance surrounded by a halo of darker reflectance, which could indicate differential drainage from mounded features. Two anomalies of this type in the 1971 image also correspond with slightly elevated areas on the 1971 and 2006 DEMs (Figures 21-22, purple). If a village was associated with Sherman Mound, these could represent past mounds or perhaps elevated residential structures, and the central area could be some sort of plaza.

The historic manuscript mentions a small mound “About 100 yards [91 m] east” of the main mound (AAS Site Survey Files). The 1971 and 2006 imagery are interpreted to have several paths crossing over this point, but it does correspond with a subtle topographic high to the immediate east of the prominent path in the 1971 DEM (Figure 21, purple). According to the 2001 survey, Area A (Figures 21-22, blue) is located on the immediate southern periphery of

Sherman Mound, and it consists of architectural, cooking, lithic, and domestic debris. Area B (Figures 21-22, yellow) may correspond to the “small mound” referenced in the manuscript. However, the 2001 sketch indicates that Area B was larger in the x and y dimensions than Sherman Mound, with the former having much more subtle topography. Area C (Figures 21-22, red) is approximately 100 m south of Sherman Mound and is situated between and around two “visual contours” that could represent parts of a mound. These roughly correspond with two slightly elevated areas of the same east-west orientation in the 1971 DEM and a larger ridge line in the 2006 DEM (Figure 21-22, purple). The same anomalies appear as prominent dark zones in the 1971 image. Lastly, a series of ditches encircling the mound were observed in the 2001 survey, which were proposed as manmade Mississippian drainage features (AAS Site Survey Files). A thin, dark ring is apparent on the outer edges of Sherman Mound in 1971 (Figure 21, brown), which could be one of these drainage features. Another of these could correspond with what was interpreted as a modern path in the 1971 and 2006 imagery and DEMs (Figures 21-22, thin black line).

The 1971 orthoimage at Sherman Mound also demonstrates a potential challenge in orthoimage interpretation. In this case, the crop rows within the central field are oriented roughly northwest-southeast. Therefore, if linear features (e.g., drainages, paths) are oriented perpendicular to these crop rows, it can present the illusion of rectangular anomalies. For example, a square anomaly was originally digitized about 100 m east from the center of Sherman Mound. Further analysis demonstrated that this shape consists of two prominent plow scars and two nearly parallel linear anomalies that are possibly drainage features. Although Sherman Mound itself is oriented northeast (perpendicular to the crop rows) and the other potential features could have similar orientations, it is unlikely that the edges of other potentially archaeological anomalies directly align exactly with the modern plow furrows. Therefore, the shapes of these anomalies also could have been distorted by the plow orientation, making them appear to have more rectangular geometries.

Given previous work at Sherman Mound, the site has a relatively high risk for potentially disturbing graves. However, future investigations at this site could consist of the acquisition of additional historic aerial images from the National Archives and/or geophysical investigations.

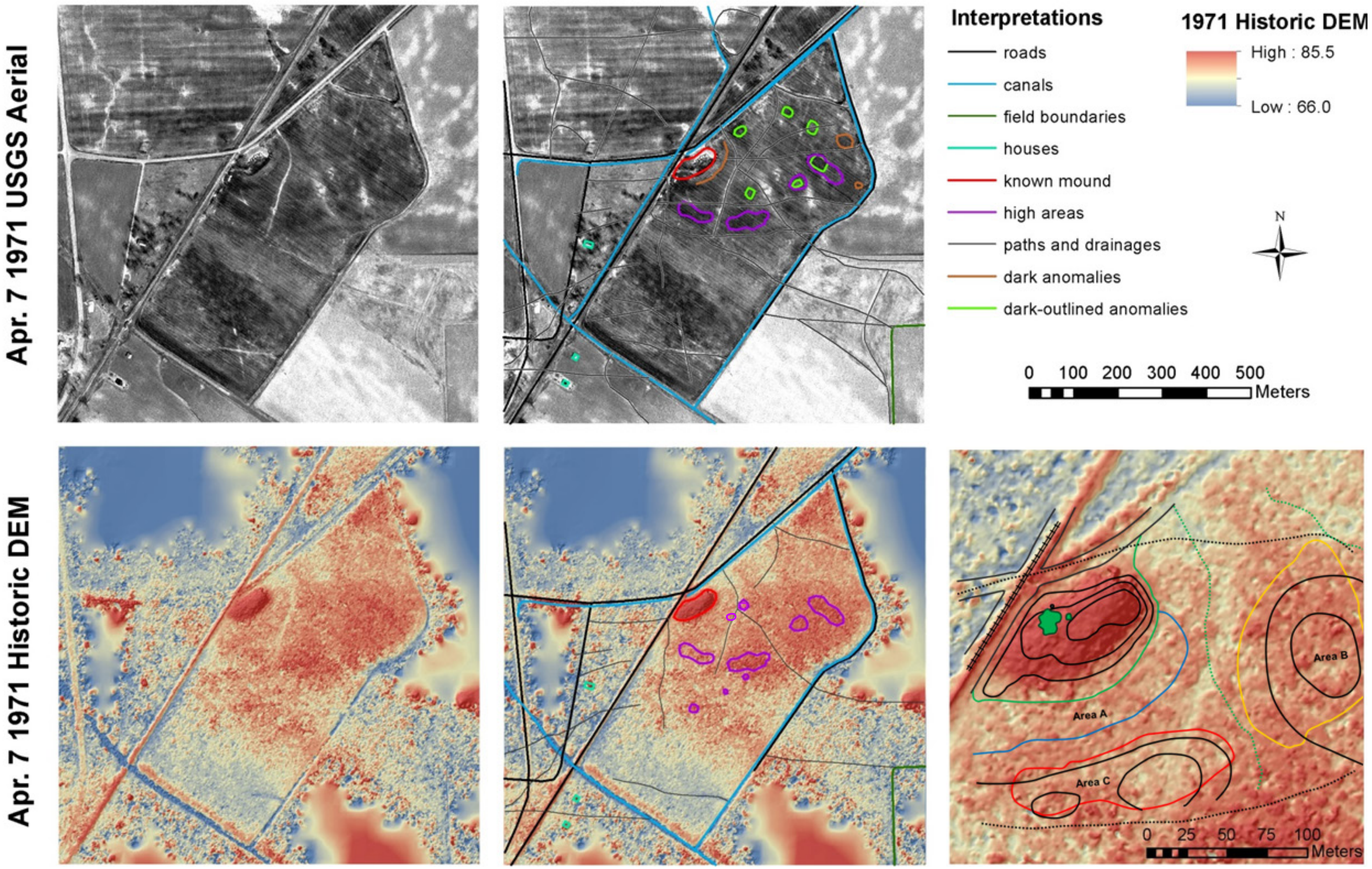


Figure 21 Sherman Mound (3MS16) interpretations of a PhotoScan-generated historical orthoimage and DEM (April 7, 1971) with 2011 sketch map for comparison (after Latham et al. 2001, AAS Site Survey Files)

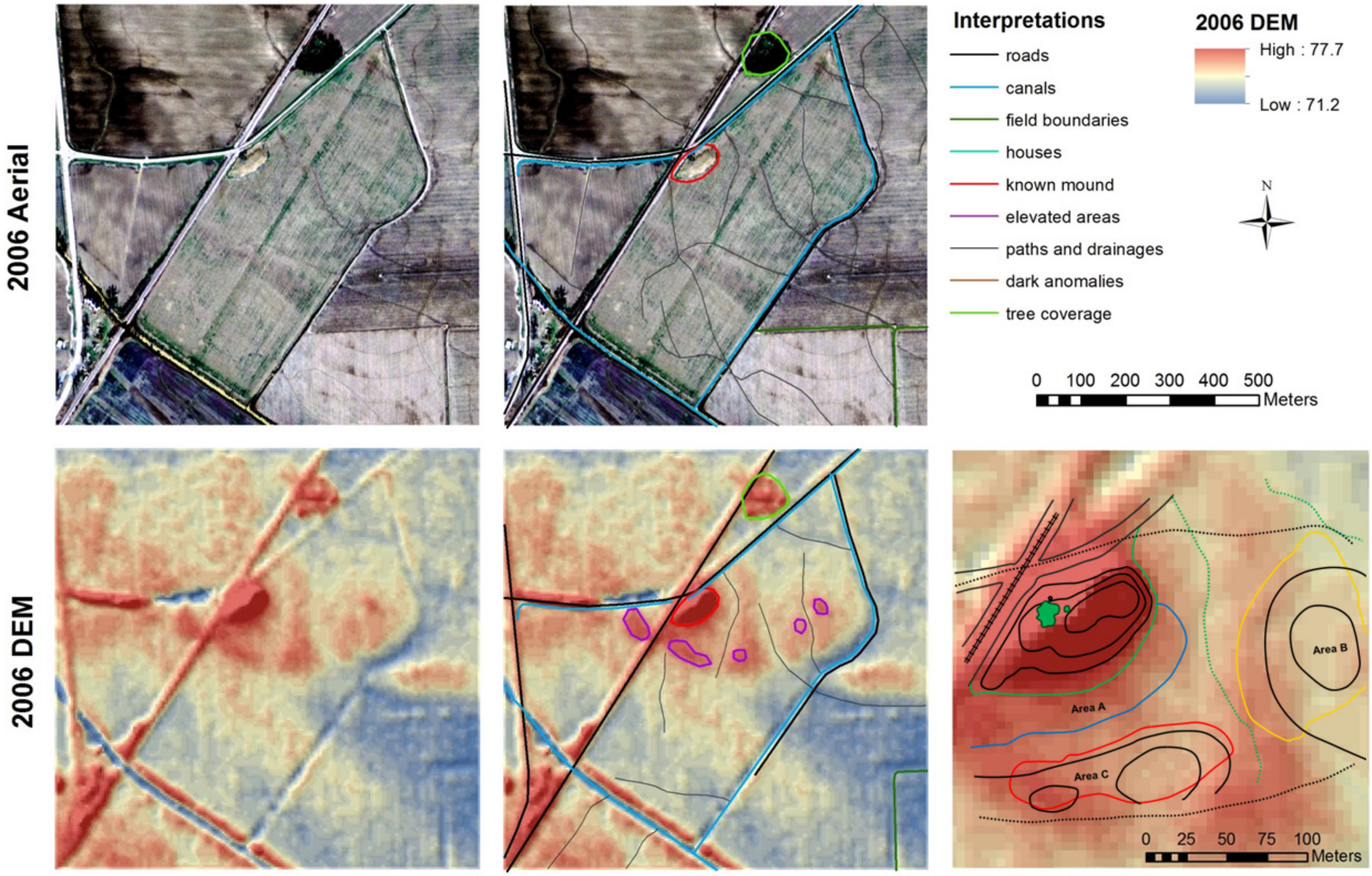


Figure 22 Sherman Mound (3MS16) interpretations of the Arkansas State Land Information Board orthoimagery and 5m DEM (Jan. 15-Mar. 31, 2006) with 2011 sketch map for comparison (after Latham et al. 2001, AAS Site Survey Files)

c. Red River and Little River Area Sites

i. Battle Mound (3LA1)

Battle Mound (3LA1) is a Middle to Late Caddo site along the Red River in west Lafayette County, featuring a large multi-platform mound. C. B. Moore and his crew visited the mound in 1912 and dug some test pits in and around it, and systematic mapping and excavation of the mound was conducted in 1948 under the direction of Krieger (McKinnon 2008:17–22). Surface collections were conducted from 1979 to the 1990s on areas labeled A-J (McKinnon 2008:22).

Available aerial imagery through EarthExplorer dates to 1948, 1949, and 1975. Of these, only the December 20, 1948 imagery was deemed suitable for analysis (Table 14).

Table 14 PhotoScan orthoimage and DEM coverage for Battle Mound (3LA1)

Agency	Acquisition Date	Scale	Download Resolution	DEM Generated
USGS	12/20/1948	32,800	High	Yes
Army Map Service	11/20/1949	70,000	Medium	No
USGS	02/25/1975	43,000	Medium	No

Despite the tree coverage, the larger mound and the known borrow pits to the immediate north and west are delineated remarkably well in the 1948 DEM (Figure 23, red and teal), and are improvements over the 2006 DEM (Figure 24, red and dark blue). A few isolated topographic lows exist in the 1948 DEM (Figure 23, dark blue), which are approximately the same size as the known pits. This could indicate that they represent similar removal of soil for the construction of elevated areas, or they could represent local topographic lows within the ridge and swale topography. Topographic highs to the southeast of the main mound can be attributed to noise in the DEM caused by trees (Figure 23, light green). However, other isolated anomalies of this kind (Figure 23, magenta) appear in clear fields, some of which may represent naturally elevated and culturally constructed activity areas. Both DEMs also detect the orientation of relict channel scars (Figures 23-24, brown) on the east side of the viewing extent.

Battle Mound was marked for follow-up analysis because of a large square anomaly (about 70 m on the side) with dark, rounded edges in the 1948 orthoimage (Figure 23, pink). The anomaly is oriented northeast, and its center is approximately 220 m from the center of the main mound. This anomaly roughly corresponds with Area J from the surface collections, a slightly elevated area that produced small quantities of artifacts in previous surface collections in 1979 (AAS Site Survey Files). Whether this rise is natural, manmade, or a combination of the two is unknown. The anomaly corresponds fairly well with the 2006 DEM (Figure 24, magenta), but less so for the 1948 DEM (Figure 23, magenta) on account of the terrain model being so variable. The outer edges of the large anomaly could represent some sort of compound fence. Such structures have been observed in excavations at other sites and have been proposed in the northern part of the Battle Mound site on the basis of magnetic data (McKinnon 2008:69–70; McKinnon 2009:253–254). However, this is not supported in the geophysical data (McKinnon, personal communication 2013). Alternatively, the outline could be attributed to differential drainage along the periphery of an elevated activity area.

Area J also corresponds with two large, circular structures with sand berms and central hearths interpreted on the basis of magnetic data and the prevalence of daub in surface collections (McKinnon 2008: 64, 87–88). Similar anomalies interpreted as structures were proposed through later magnetic gradiometry surveys between Area J and the mound (McKinnon 2010). Two circular, dark-edged anomalies in the 1948 image (Figure 23, pink) exist within the larger square, but the edges are more difficult to distinguish. These are aligned in a northeast configuration, as opposed to the north-south configuration of the two magnetic anomalies, but could partially overlap with one of the proposed structures from the magnetometry data.

Three square anomalies about 20 m on the side appear in the 2006 image (Figure 24, purple). Their orientation corresponds with the striping pattern of cultivation and may not actually represent cultural disturbances of the soil, but they are similar in shape to each other and are slightly oblique to the cultivation pattern. They are approximately in the location of Area E, which was thought to be a plowed-down mound on the basis of its light artifact concentration, soil contrast, and minimal vegetation growth (AAS Site Survey Files), but is more likely a naturally occurring rise within the ridge and swale topography, noted by C. B. Moore in 1912 and the 1948 excavations (McKinnon, personal correspondence 2013). It was characterized as a low rise, but this kind of topographic signature is not apparent in the 1948 or the 2006 DEM.

Another anomaly exists to the southwest of the main mound in 1948, consisting of an area of dark reflectance, an area of light reflectance, and a light rectangular anomaly cross-cut by these two halves (Figure 23, pink and tan). The dark half corresponds with a topographic low and the light half corresponds with a topographic high. The dark half also corresponds to a series of dark anomalies in the 2006 orthoimage (Figure 24, purple), oriented around the mound and northwest, connecting to the extant stream channel. This suggests that this anomaly can be attributed to a drainage feature.

A series of prominent meander scars are present in the southwest viewing area of all orthoimages and DEMs (Figures 23 and 24, brown). A dark, roughly rectangular anomaly (Figure 23, purple) is present about 150 m to the northeast of the mound. This anomaly lies between two apparent meander-scar ditches, and could represent a locally depressed area of differential drainage, possibly from the manual removal of soil.

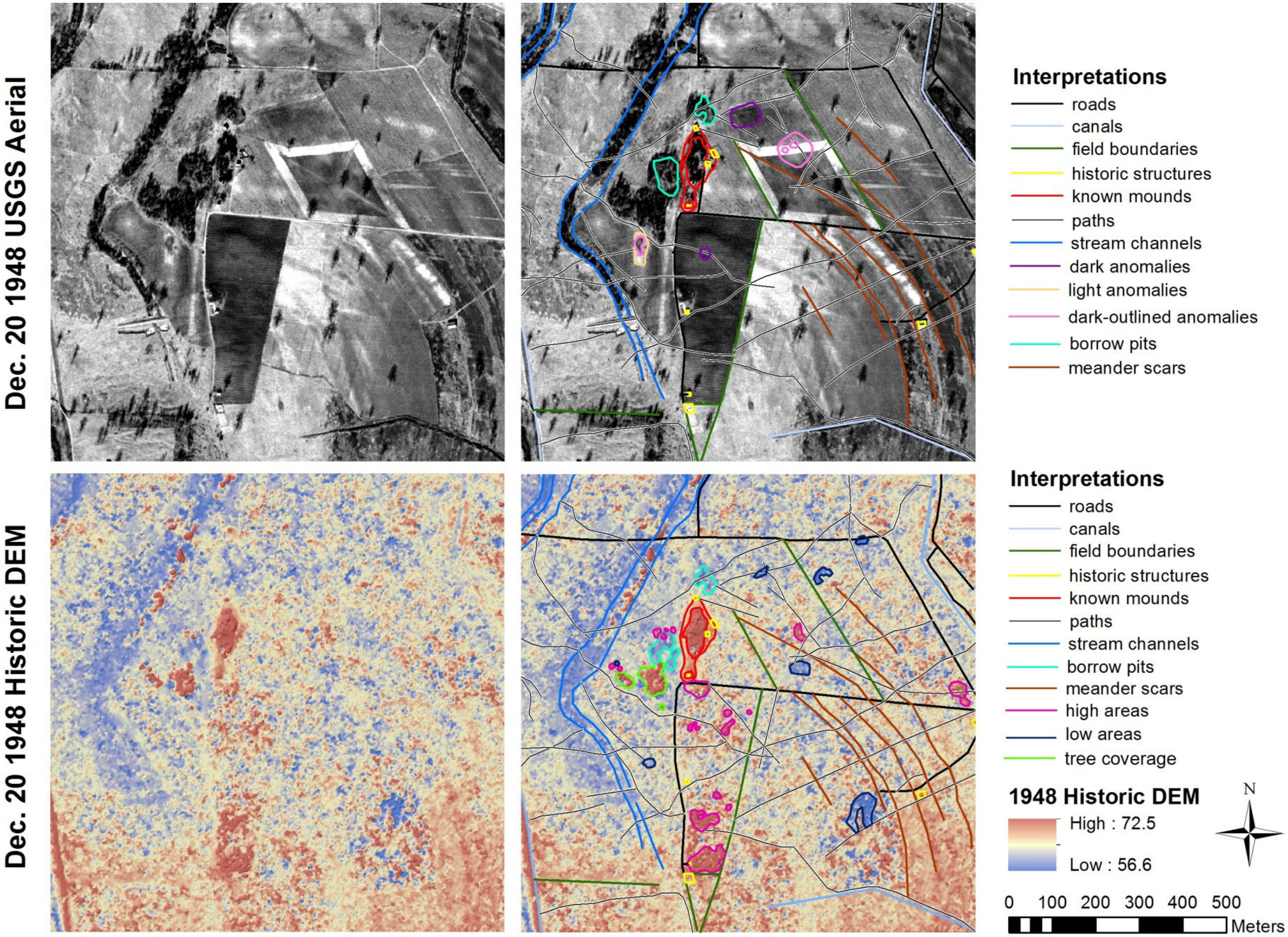


Figure 23 Battle Mound (3LA1) interpretations of a PhotoScan-generated historical orthoimage and DEM (December 20, 1948)

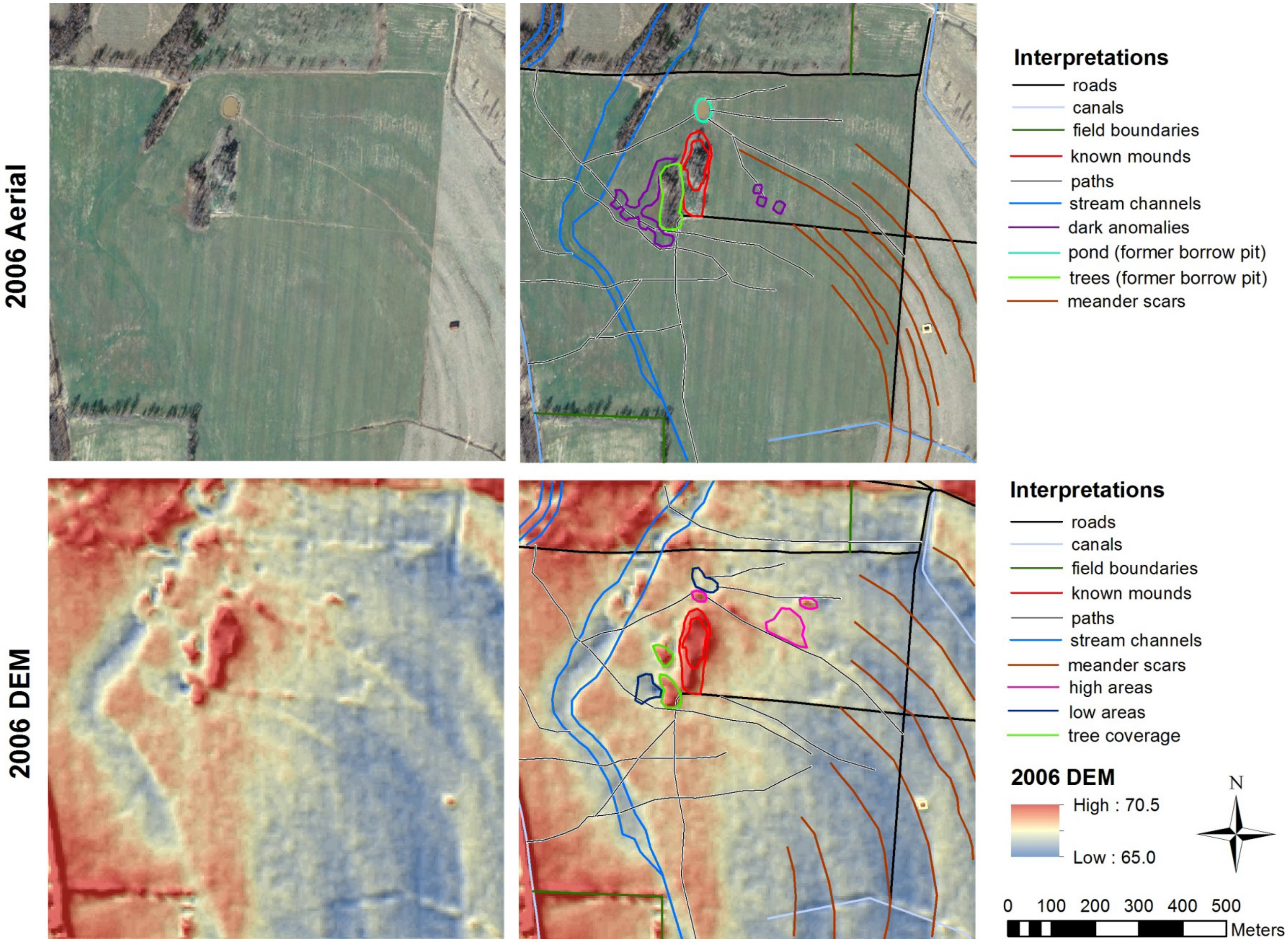


Figure 24 Battle Mound (3LA1) interpretations of the Arkansas State Land Information Board orthoimagery and 5 m DEM (Jan. 15-Mar. 31, 2006)

ii. Crenshaw Mounds (3MI6)

Crenshaw Mounds (3MI6) is a Fourche Maline to Early Caddo site located in the northeast part of Miller County along the Red River. It has six mounds (labeled A-E) and several cemeteries, and a large concentration of deer antlers was excavated in the southern part of the site. Although considerable work has already been conducted at the site with regard to geophysical surveys and excavations, the aerial images present some additional anomalies that could represent previously unknown archaeological features.

Aerial images for the winter months of 1948, 1949, 1970, and 1975 are available from Earth Explorer (Table 15). Of these dates, the 1948 and 1949 imagery and resultant DEMs were analyzed in more detail because of their age, scale, and high-resolution downloads.

Table 15 PhotoScan orthoimage and DEM coverage for Crenshaw Mounds (3MI6)

Agency	Acquisition Date	Scale	Download Resolution	DEM Generated
USGS	12/20/1948	32,800	High	Yes
USGS	01/06/1949	32,800	High	Yes
Army Map Service	11/20/1949	70,000	Medium	No
USGS	02/18/1970	29,600	High	No
USGS	02/25/1975	43,000	Medium	No
Ames Research Center	03/07/1982	65,000	Medium	No

The images available from the 1940s are only 17 days apart, and the orthoimages reveal similar anomalies. However, the January 6, 1949 produced a smoother DEM, which could be attributed to the higher level of contrast in the 1948 photograph in comparison to the 1949 image. Although a certain level of pixel contrast is needed in order to align and create a surface model from the images, too much contrast can have a noisy effect. The 1949 DEM clearly delineated known features, both modern (e.g., fields, roads) and archaeological (e.g., mounds). This suggests that, if erroneous geometry is produced when unmodified images are used in

PhotoScan, subtle adjustments to the contrast settings and the use of a low-pass filter may improve performance. Overall, both the 1948 and 1949 orthoimages and DEMs clearly delineated tree-covered Mounds C, D, and F. Mound B (Figures 25-26, red) was completely excavated between 1933 and 1935 (Samuelsen 2009:37–38) and is less visible in both images. All mounds except B and D have visible topographic relief in the 2006 DEM (Figure 30, red), but the topographic signature for mound C is more subtle than for A, E, and F. This reduction of Mound C can be attributed to an almost total excavation of it in 1961 (Samuelsen 2009:44).

In the 1948 and 1949 images (Figures 25 and 27), Mound A, Mound E, and their connecting causeway are in a wooded area. Although the forest boundary curves slightly outward around the larger Mound A, both mounds would be virtually undetectable on the basis of the 1940s photographs alone. However, both of the resultant 1948 and 1949 DEMs (Figures 26 and 28, red) placed the mounds in elevated areas (i.e. taller vegetation). This indicates that the PhotoScan-generated DEMs could potentially be of use in forested areas for locating large structures such as mounds. With this in mind, an elevated circular anomaly in the northwest part of the 1949 DEM (Figure 28, magenta) could represent a smaller, unknown mound.

A northeast-southwest trending square outline of approximately 60 m x 60 m (Figures 25, 27, and 29, blue) is located around Mound B, which could represent some sort of enclosure or a ditch encompassing the mound. The southeast side appears to correspond with a linear drainage anomaly (Figures 25-30, dashed line), and the northeast side corresponds with a southeast-trending natural ridge (Figures 25-30, gray). Because Mound B was completely excavated in the early 1930s, the darker area of vegetation interpreted as the mound could in fact be the backdirt pile, which could place the square off-center from the mound. The square anomaly exhibits a light-dark-light transition on all of its borders, which could suggest that it was a manmade feature with limits constrained by the linear ditch and natural ridge line. Alternatively, the construction of a ditch or ridge around the mound could have contributed to the formation of a peripheral linear drainage. The 1948 DEM shows two subtle L-shaped depressions that correspond to the easternmost corners of the square, as well as another small linear depression that matches with the northeast corner (Figure 26, blue).

The 1940s DEMs effectively detected linear anomalies such as paths, streams, field boundaries, and canals. In particular, a series of east-northeast-trending linear depressions were interpreted as trails and/or drainage features and were consistent in orientation with linear anomalies on the corresponding orthoimages (Figures 25-28, dashed line). Although most of these are probably historic to modern and not contemporary with the site, it highlights a possible strength of such DEM generation methods for archaeological prospecting.

This example also demonstrates a potential challenge to interpretation and the importance of comparing the original aerial images with the final PhotoScan mosaic. A series of small dark anomalies in the 1948 photograph (Figure 25, purple) changed their positions between two images used for the stereopair (Figure 31), indicating either subtle differences in lighting (i.e., from moving clouds) between the two images or that they are not fixed features on the ground surface. If the latter, this indicates that the small dots digitized on the 1948 image are not actually of archaeological significance. Relying on the resultant mosaic alone, the researcher cannot distinguish mobile versus fixed anomalies. However, some of the larger dark anomalies apparent in the 1949 image (Figure 27, purple) did not move, and match the 1948 image. These could be associated with ancillary structures around the mounds. Dark linear and amorphous anomalies appear around Mound D (Figures 25 and 27, purple). The former appears to be of possible fluvial origin, whereas the latter could represent activity areas around the mound.

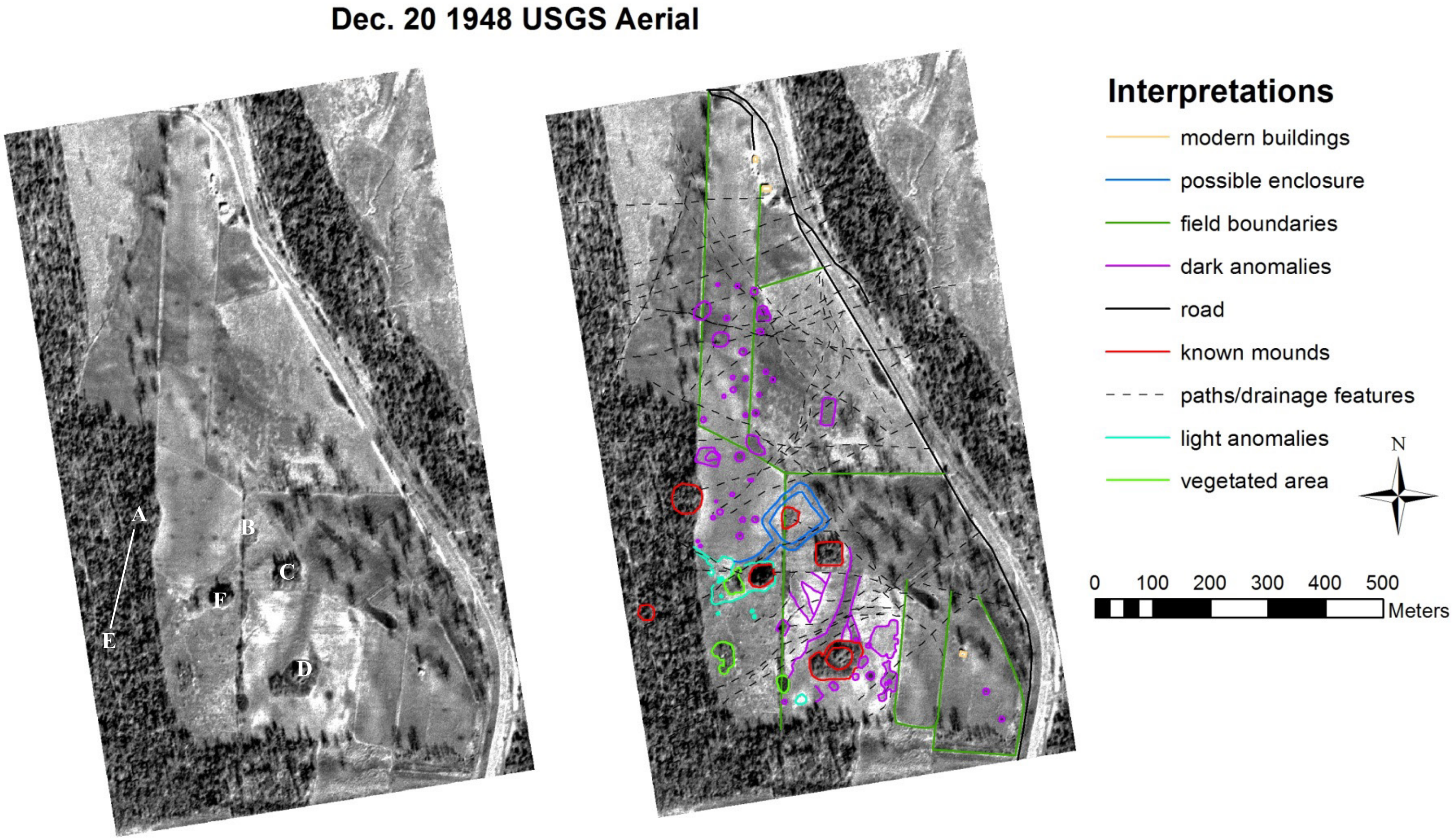


Figure 25 Crenshaw Site (3MI6) interpretations of a PhotoScan-generated historical orthoimage (Dec. 20, 1949)

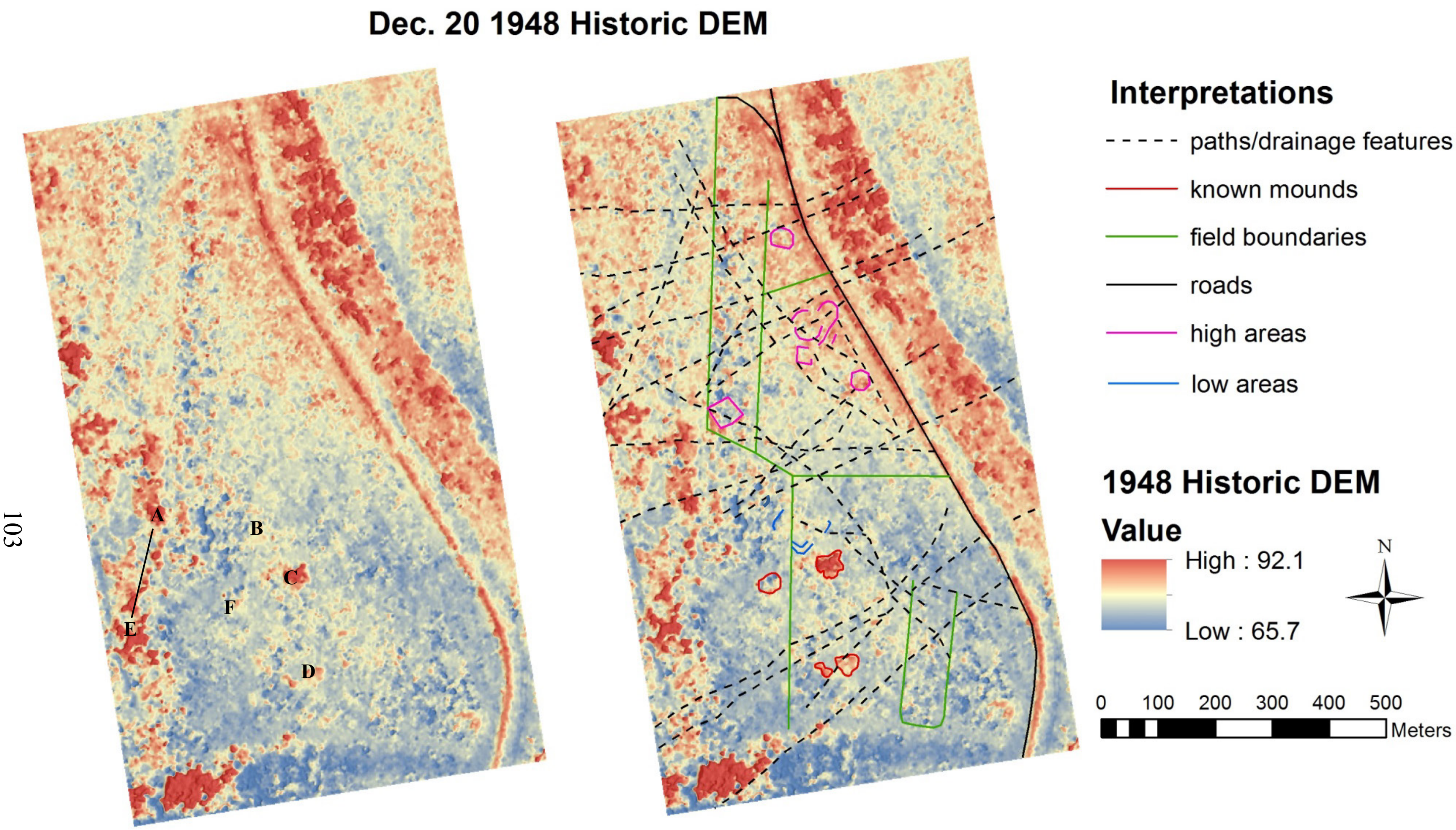


Figure 26 Crenshaw Site (3MI6) interpretations of a PhotoScan-generated historical DEM (Dec. 20, 1949)

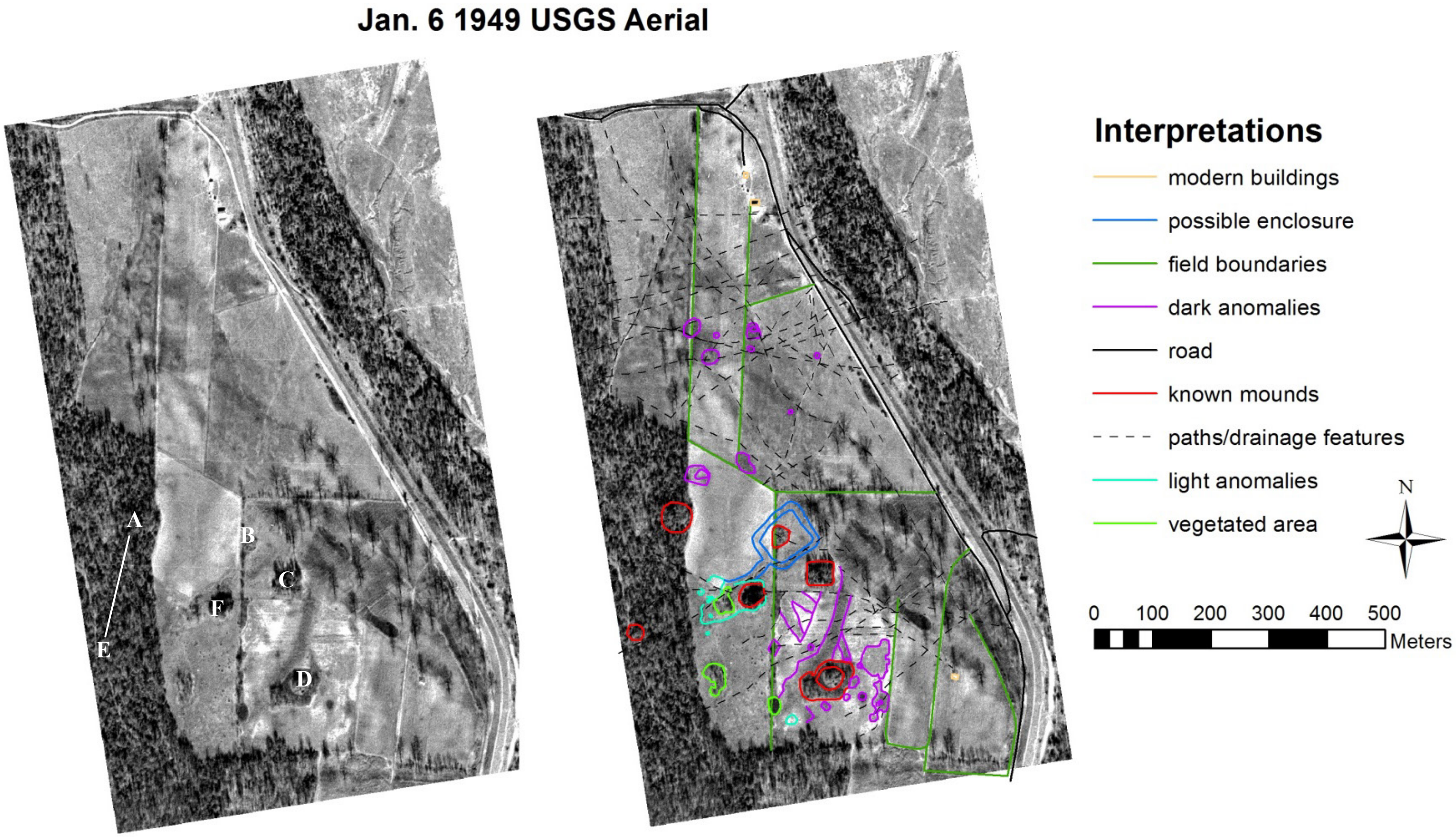


Figure 27 Crenshaw Site (3MI6) interpretations of a PhotoScan-generated historical orthoimage (Jan. 6, 1949)

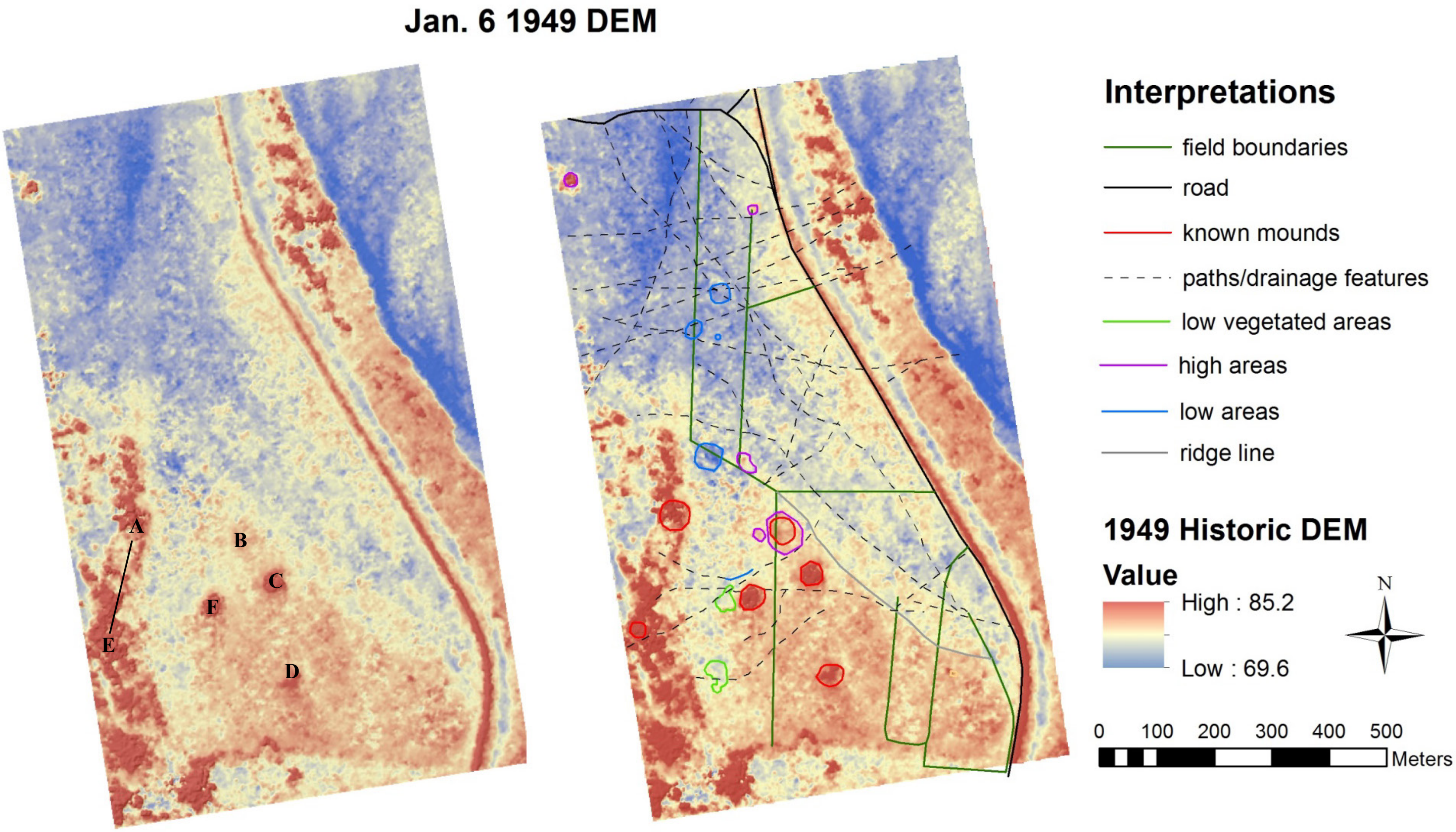


Figure 28 Crenshaw Site (3MI6) interpretations of a PhotoScan-generated historical DEM (Jan. 6, 1949)

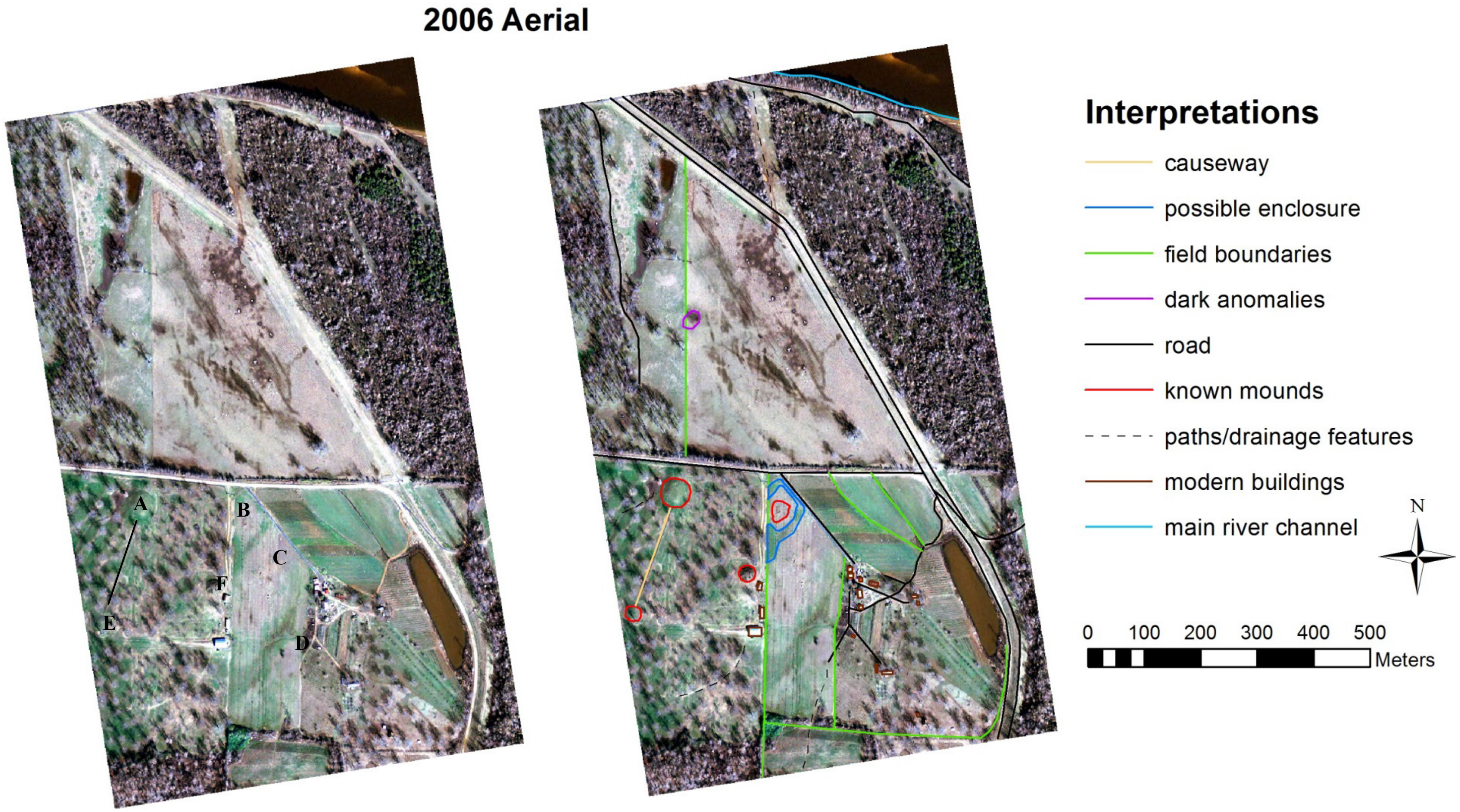


Figure 29 Crenshaw Site (3MI6) interpretations of Arkansas State Land Information Board orthoimagery (Jan. 15-Mar. 31, 2006)

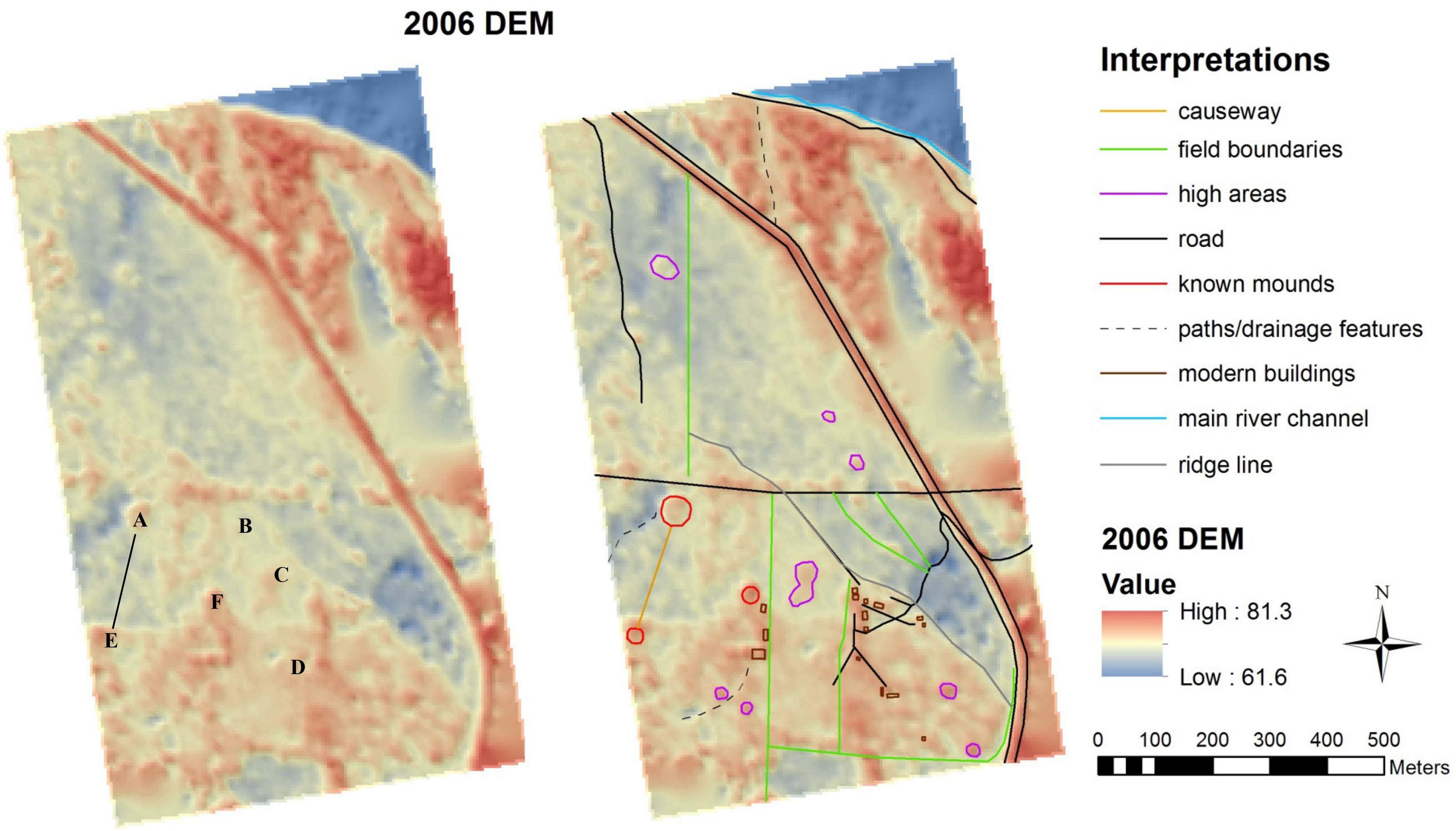


Figure 30 Crenshaw Site (3MI6) interpretations of the Arkansas State Land Information Board 5m DEM (Jan. 15-Mar. 31, 2006)

Figure 31 Comparison of two adjacent aerial images from January 20, 1948. Note the movement of the small dark anomalies, particularly within the boxed regions. Although the general lack of correspondence could suggest that these are not fixed features on the ground, this could also be attributed to subtle differences in lighting between the two images. The dark spots bordering the white dotted circle (upper left) were originally interpreted as possible cultural anomalies in the mosaicked imagery, but are not clearly expressed in the image to the right.

IV. CONCLUSIONS AND FUTURE DIRECTIONS

A. CONCLUSIONS

1. Utility of Aerial Imagery for Regional Prospecting

Research Question 1: Can historical aerial images be successfully utilized for site prospecting on a regional scale in Arkansas? If so, what kinds of imagery and site types are amenable to aerial prospecting?

For the selected study regions in Arkansas, the initial visual assessment revealed that specific site types are amenable to prospecting via EarthExplorer's historic aerial imagery. These include primarily (1) large sites with significant mounds, earthworks, or middens and (2) historic structures. Given the ease of producing extensive regional orthoimagery in PhotoScan, archived imagery could be used to search for similar, yet undocumented site types in other parts of the United States. Because archaeological survey coverage in most areas is highly uneven (i.e., driven by needs of CRM projects and constrained by land ownership), historic aerial images provide a rare opportunity to investigate unexplored areas, which may no longer yield visible site types due to sustained land-use practices.

Index maps and individual single frames for the National Archives' holdings are not currently available online at this time. Therefore, for extensive regional coverage required for prospecting, this presents some cost restrictions for individual researchers who must order them from venders for reference, and additional logistical constraints for those intending to visit the Archives to photograph the images themselves. Provided that one invests in a license for Agisoft PhotoScan Pro ($549 for an Educational License) and has access to a computer with enough RAM to meet the processing requirements for the software, the combined use of EarthExplorer and PhotoScan is a highly cost-efficient method for obtaining widespread historic orthoimagery.

Furthermore, EarthExplorer has early USDA aerial images dating to the 1940s and 1950s, some of which are high-quality downloads that are ideal for processing and interpretation. (Refer to Appendix A for single frames with high-resolution downloads greater than 1:35,000 in scale.)

Overall, confidence in site recognition improved with increased familiarity with local site morphologies. Although some sites undoubtedly will be missed in the early stages of classification, sites can be assessed for visibility on the basis of simple principles (e.g., color changes, geometric shapes) without much *a priori* knowledge of site appearance types. As more sites are located, this provides a reference to better inform future aerial interpretations, and researchers will become more adept at identifying site features. Therefore, two key objectives include: (1) the construction of integrated site and historic aerial imagery databases and (2) training researchers in site recognition, which is a learning process that develops with continued exposure to different site types as they appear on these media. For example, in other parts of the United States, one can effectively apply the procedure presented here, starting in areas with previously known archaeological sites to establish prioritized site-type indexes. This knowledge can then be used for site prospecting in unexplored regions with similar cultural and environmental parameters.

The quality of the high-resolution downloads exceeded expectations, particularly with regard to the 1940s aerial images of southwest Arkansas. In general, high-resolution downloads of 1:35,000 scale or larger worked well for orthoimage and DEM production and interpretation. Medium-resolution downloads 1:15,000 or larger were suitable for archaeological interpretation of individual sites. Photographs should also be assessed for contrast, which depends the settings of the camera as well as environmental factors at the time the photographs were taken. The winter months generally presented good contrast, provided that the other criteria for download quality and geographic scale were met. Pre-processing low-contrast images prior to their use in PhotoScan may improve performance, but this was not analyzed here. Older images were preferable because the anomalies are less likely to be attributed to modern disturbances; however, forested areas sometimes obscured known archaeological features.

As with all prospecting methods, aerial prospecting is biased towards certain types of sites, even with the AMASDA coordinates as a reference. Primarily structures of high topographic relief and soil displacement (i.e. mounds), structures with sharp boundaries (i.e. historic structures), and areas with strong color contrasts with the surrounding soils (i.e. middens) were detectable. Unless accompanied by substantial displacement or anthropogenic modification of soils, artifact scatters were not detected at the scale of observation of the aerial single frames. The intrasite case studies provide additional site characteristics that aided in the delineation of archaeological features. Overall, open agricultural fields provided a wide spectrum of anomalies for consideration. Soil composition also played a role, and should be investigated in more detail. For instance, the sandy soils of the Armstrong Site (3CG64) were useful for detecting mounds.

The methods used in this study can be used to recreate past cultural landscapes that have been partially or completely demolished through decades of land modification for agriculture, construction, etc. Not only do the archived aerial images show how land was used in the past, but they also provide the only topographic indicators of past archaeological structures, which have since been land-leveled or otherwise destroyed. Particularly for the 1940s imagery, the high-resolution DEMs very effectively delineated areas of substantial topographic relief, which could be verified and corroborated with extant archaeological knowledge.

2. Utility of Aerial Imagery for Intrasite Prospecting

Research Question 2: At the intrasite level, can the aerial images and PhotoScan-generated DEMs reveal previously known and unknown features and structures?

The ability to create custom historic orthoimages and DEMs for specific sites represents a major step forward in archaeological prospecting using historic aerial imagery. As demonstrated in the previous case studies, the orthoimagery available through EarthExplorer alone provide ample opportunities for proposing possible soil disturbances from past cultural activities. PhotoScan's geometric models very clearly reproduced the geometries of grooves and ridges, ranging from stream channels to possible historic trails. Furthermore, both tree-covered and barren mounds were modeled with relatively high precision, as well as topographically depressed areas such as borrow pits. Other smaller topographic anomalies were very useful in interpreting corresponding anomalies in reflectance and for proposing additional areas for future analysis.

Although this level of high-resolution DEM processing would not be practical at the county level, it could very feasibly be incorporated into a nested structure of site survey for individual archaeological projects. By selecting a specific area of interest (e.g., a river valley), the process of orthoimage production and medium-resolution DEMs would be easy, and one could conduct a detailed search for potential sites within that extent. For anomalies of potential archaeological interest, higher-resolution processing could be conducted in the same fashion as the intrasite analysis. Afterwards, in carrying out standard surveying procedures in the field, we can learn more about the origins and material properties of the anomalies. This iterative process of aerial prospecting and verification via ground surveys would promote the systematic classification of anomalies.

3. Implications for Cultural Resource Management Practice

This generation and utilization of historic aerial imagery provides a base layer for many promising avenues of study. Potential features of at least some sites are visible, and the development of regional aerial archaeology databases is a highly feasible goal with the use of new photogrammetric software. Systematic analysis of aerial imagery and comparisons with other archaeological data could provide a launching point for the development of aerial archaeology programs in the United States.

The methods used in this study provide a relatively fast, inexpensive means of obtaining historic orthoimagery coverage for entire counties, depending upon the availability of the images on EarthExplorer. The creation of historic DEMs is a simple procedure in PhotoScan and can easily be exported into GIS software. Topographic models generated for specific sites within the study region were highly advantageous for interpreting potential intrasite features. Custom generated DEMs primarily detected heavily vegetated areas, major roadways, and canals. Granted, the DEMs were not perfect and performed better for some sites than others. For instance, presumably flat sites such as Old Town Ridge sometimes were modeled with irregular "noisy" curvature, and CG991 exhibited false undulating curvature in the DEM. However, overall, they provided good approximations for the sake of historic landscape visualization. Furthermore, the quality of the DEMs may be improved with additional experimentation with image processing, tweaking with the parameters within the program itself, or testing in areas with more drastic topography. In contrast to agricultural examples, DEMs produced in PhotoScan could be more accurate for river valleys and reservoirs, which are of considerable interest for archaeological prospecting.

Excluding the occasional trial and error troubleshooting and experimentation, another benefit of using PhotoScan for orthoimage generation is that it is an intuitive program. Although PhotoScan is essentially a "black box," the operations are very straightforward, and the program does not entail much technical training to use. Furthermore, the correctness of the output is easily validated through comparison with extant maps and downloadable GIS data. For this study, comparisons with modern orthoimages indicate that the resultant historic images are fairly accurate (within 20 m) provided that sufficient, well-distributed ground control points are used and that they are accurately placed. Errors in georeferencing can be reduced by modifying the GCPs and re-exporting the image.

Overall, historic aerial imagery should be an essential component for archaeological prospecting. Similar to geophysical surveying, aerial image analysis can provide a non-invasive means to map out known and potential archaeological features of interest that should be avoided by federal agencies. Anomalies present in the orthoimagery and DEMs can be used to plan pedestrian surveys, shovel tests, and geophysical explorations. From an academic standpoint, intrasite analysis can propose new features, encouraging revisitation for research and site status assessments. For instance, sites previously determined as ineligible or of undetermined eligibility for nomination to the National Register of Historic Places may be reassessed in light of new evidence.

B. FUTURE DIRECTIONS

1. Revisitation of Visible Sites

The intrasite analyses presented herein have identified many potentially cultural features located within and surrounding known sites. These features include possible unrecorded mounds, ditches, and other earthworks and represent some of the most significant archaeological findings of this study. In some cases, previous surveys and excavations support interpretations of aerial imagery; in other cases, it will be necessary to ground-truth features to determine whether or not they are in fact of cultural origin.

In light of the conclusions made from the analysis of the visible sites, possibly visible sites should be reexamined on the orthoimagery to see if they can be reclassified as visible. Because the site visibility classification scheme utilized represents a learning process, certain anomalies may be easier to recognize. This is particularly true for sites examined early in this process, as well as major archaeological sites that were determined as possibly visible or invisible in the first assessment. This iterative examination in conjunction with other forms of archaeological data is central to developing further strategies for employing the method.

2. Creating Regional Aerial Image Databases

In addition to the internal settings of the camera and its position with respect to the ground surface, various environmental and temporal factors combine in unique ways and ultimately affect how sites and features appear on aerial imagery. Although we can account for some of these variables through planned surveys, aerial prospecting is largely serendipitous in nature. This is particularly true for imagery produced via systematic aerial surveys. Therefore, older images, different years, and different image datasets could potentially reveal many more features and site types than presented here. This makes the creation and expansion of regional aerial image databases of critical importance.

Working in collaboration with the Arkansas Archaeological Survey, this method of historic orthoimagery production and interpretation could be applied to other areas of Arkansas to expand the historic aerial coverage. This first should be done with the free EarthExplorer

Single Frames, as demonstrated in this study. This would not only provide materials to further develop methods of aerial image interpretation for Arkansas, but it would also provide a frame of reference for ordering older and better images elsewhere (e.g., the National Archives in College Park, Maryland; the USDA's Aerial Photography Field Office in Salt Lake City, Utah).

For individual sites or regions of particular interest, additional photographs can be obtained to see how their visibility changes through time and in different seasonal conditions. Future collaboration with the National Archives would be advantageous for advancing this kind of research. Taylor and Spurr (1973) provide a two-part index of the National Archives aerial photograph holdings, organized by county surveys for each state and special project surveys. For each county, the following data are provided: the reference symbol, photograph year, number of index maps held by the Archives, and the agency that conducted the survey. For the special project surveys, the name of the survey, counties covered, number of indexes, and geographic scale of the photographs are provided.

Although the National Archives do not permit individual researchers to scan the aerial negatives, researchers are permitted to photograph them. The use of a digital camera would introduce some distortions in the imagery itself, but they very likely could be processed in PhotoScan without seriously compromising the quality of the orthoimages. This assertion is supported by the fact that successful orthoimage generation was possible for the Medium Resolution downloads from EarthExplorer, which are digital photographs of the original negatives. These images were not adequate for archaeological purposes because of the resolution of the camera (400 dpi). However, if images were captured at a resolution comparable to the scans (1,000 dpi), then they could be similarly processed as long as the accompanying metadata (e.g., focal length, film dimensions) are recorded. As such, it would be highly feasible to send researchers to the National Archives to photograph negatives for areas of interest. Developing some sort of working relationship with the University of Maryland could be another viable alternative, given the proximity of the Archives to the College Park campus. Lastly, because official venders approved by the National Archives are permitted to directly scan photographs, academic institutions could apply for vender status.

Future investigations could concentrate on Garland and Montgomery counties in west-central Arkansas. These counties were originally going to be included in this study because they encompass the Hot Springs area, as well as the Lake Ouachita (constructed 1946-1953), Lake Hamilton (1932), and Lake Catherine (1924) reservoirs. They were excluded due to time constraints and because a limited range of dates and geographic extents are available for the aerial imagery via EarthExplorer. However, this region has great potential for future analysis of images available in the National Archives. In particular, images that predate these reservoirs could be used to find archaeological sites that are now inundated. As part of the Ouachita Mountains region, the images are more susceptible to distortion due to changes in topography, and the more dramatic topography may allow for more successful 3D reconstructions of site landscapes.

Other areas expected to have high surface visibility for archaeological sites include the southeast lower Mississippi Valley and areas along the Arkansas River in central Arkansas. These areas were not included in the present study due to time constraints, but would provide promising starting points for future analyses. For instance, high-resolution, large-scale 1940s imagery is available for Saline and Pulaski Counties along the Arkansas River, as well as Hot Spring, Fulton, and Izard Counties. (See Appendix A for coverage for other years.)

Again, although this study focused on imagery within Arkansas, it could easily be applied to other regions of the United States. From this, highly advantageous aerial databases could be developed that could provide a model for aerial investigations elsewhere. Furthermore, this kind of procedure and preliminary analysis can guide future research by indicating which photographs one should order, what resolutions and seasons seem to highlight certain archaeological features, and for planning custom flight missions over archaeological sites.

3. Integration with Other Data

High-resolution imagery: A major shortcoming of this study is that investigations of seasonality were limited. Generally, the USGS historic photographs available on EarthExplorer represent a limited range of months from late autumn to early spring (November-April). Of these, an even narrower range are high-resolution downloads of scales appropriate for archaeological prospecting. To monitor intrasite feature visibility with respect to seasonal conditions and modern land use, additional imagery could be obtained from the National Archives, as well as from high-resolution satellite imagery. Visible-light and multispectral coverage is available from the USGS (e.g., Digital Orthophoto Quarter Quads), the National Agriculture Imagery Program (NAIP), Quickbird, and IKONOS. For reference, Forte and Williams (2003) and Parcak (2009) provide diverse examples of satellite and aerial remote sensing applications in archaeology worldwide.

LiDAR: For Arkansas, a 5 m DEM is available for all counties. Three-meter National Elevation Datasets (NEDs) and LiDAR coverage are currently being developed at this time. These represent topographic conditions in the past decade, which in some areas is drastically different than the time of the historic aerial coverage, but the high level of precision will be extremely advantageous for future research. Furthermore, future work could use GCPs derived from DEMs of varying vertical precisions to georeference historic DEMs in PhotoScan. Although PhotoScan can generate landscape geometry without the use of GCPs, the incorporation of GCPs from different DEMs would affect the precision of the models, and the degree of variability would be worth investigating.

Geophysical and UAV Surveys: The methods presented here would be useful for planning stages of future geophysical surveys. Although preliminary aerial analysis prior to geophysical is a standard recommended procedure, the use of photogrammetric software such as PhotoScan provides a much more nuanced set of data for inference than the aerial images alone. Areas with extant geophysical data should be compared with PhotoScan orthoimages and DEMs to characterize the appearance of cultural and geomorphological features. In addition to ground-based geophysics, other remote sensing data could be used for interpretation, and this most effectively can be done for specific sites through the use of UAVs. UAVs provide a cost-effective means for following up on anomalies discovered from the archived aerial imagery. Although they present the present conditions of the landscape, they can be used to capture site-specific aerial photography for photogrammetric processing, as well as other forms of data such as near-infrared and thermal imagery. Combined with the historic images, geophysics, and ground-based investigations, archaeologists will have a wide spectrum of corroborative evidence for interpretations. Furthermore, these instruments would provide the temporal flexibility for repeated surveys of known archaeological sites to investigate seasonality.

Environmental Data: This study provides a preliminary investigation of trends in visibility according to photograph characteristics and basic site categories, but much more could be done in terms of investigating environmental parameters. Focusing on particular types of archaeological sites, visibility could be reassessed in terms of the environmental settings of the sites (e.g., soil types, modern land use, topography, terrain variance). For instance, modern land use could be used as a proxy for surface visibility in that certain types of agricultural fields may be more amenable to site visibility. These kinds of data are available as GIS layers through GeoStor (www.geostor.arkansas.gov) or the USDA NRCS Geospatial Data Gateway (datagateway.nrcs.usda.gov). Historic weather data for scattered research stations are also available through the NOAA's Global Historical Climatology Network (GHCN). Data from stations within one's area of interest could be used to approximate the local environmental conditions at the time the historic aerial photographs were taken.

It would be worthwhile to compare sites with similar characteristics that were classified as visible versus not visible or ambiguously visible. These comparisons could isolate variables that contribute to or detract from visibility. If strong correlations between visibility and environment exist for specific site types, then these could be used for predictive modeling. Such models could guide the acquisition of additional imagery and lead to new and exciting discoveries.

Collectively, integration of historic aerial imagery with other forms of data would provide a strong basis for the creation of regional aerial survey programs and aerial imagery databases in the United States. As mentioned in the introduction, Dollar (1962) encouraged Arkansans search for a "pilot site," a clearly visible archaeological site that would inform aerial prospecting. In this study, several sites have been found with promising proposals for future investigation—Dollar's search for a "pilot site" in Arkansas is over.

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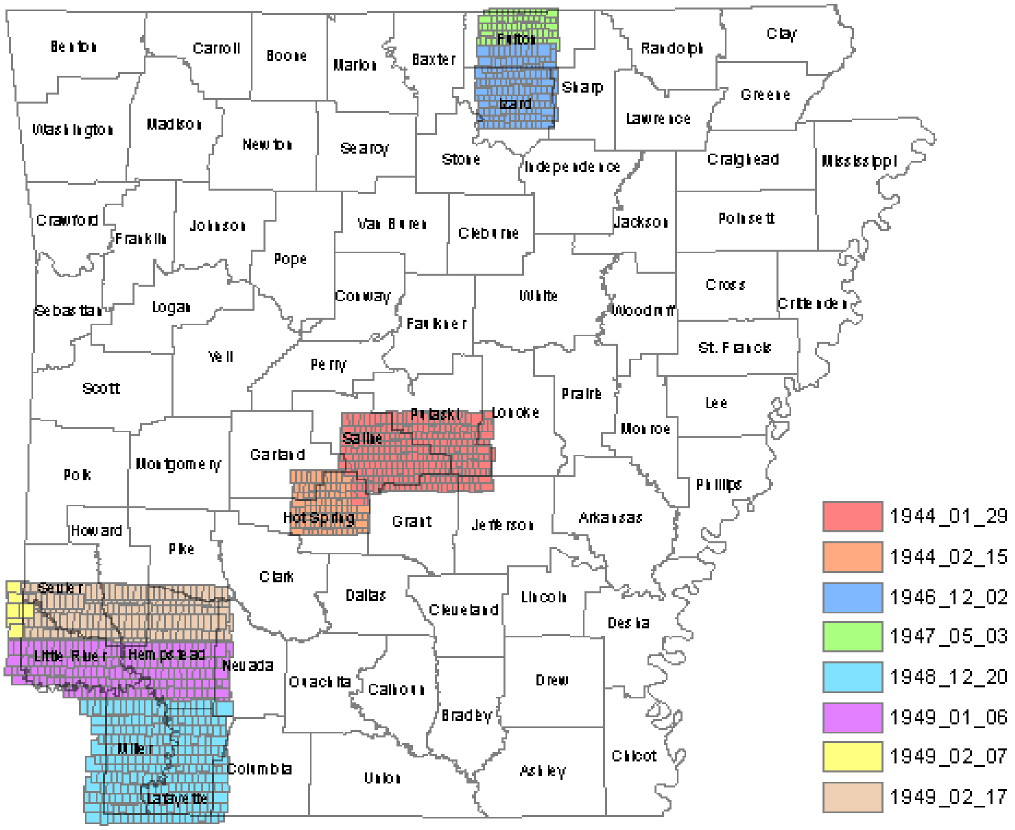
VI. APPENDICES

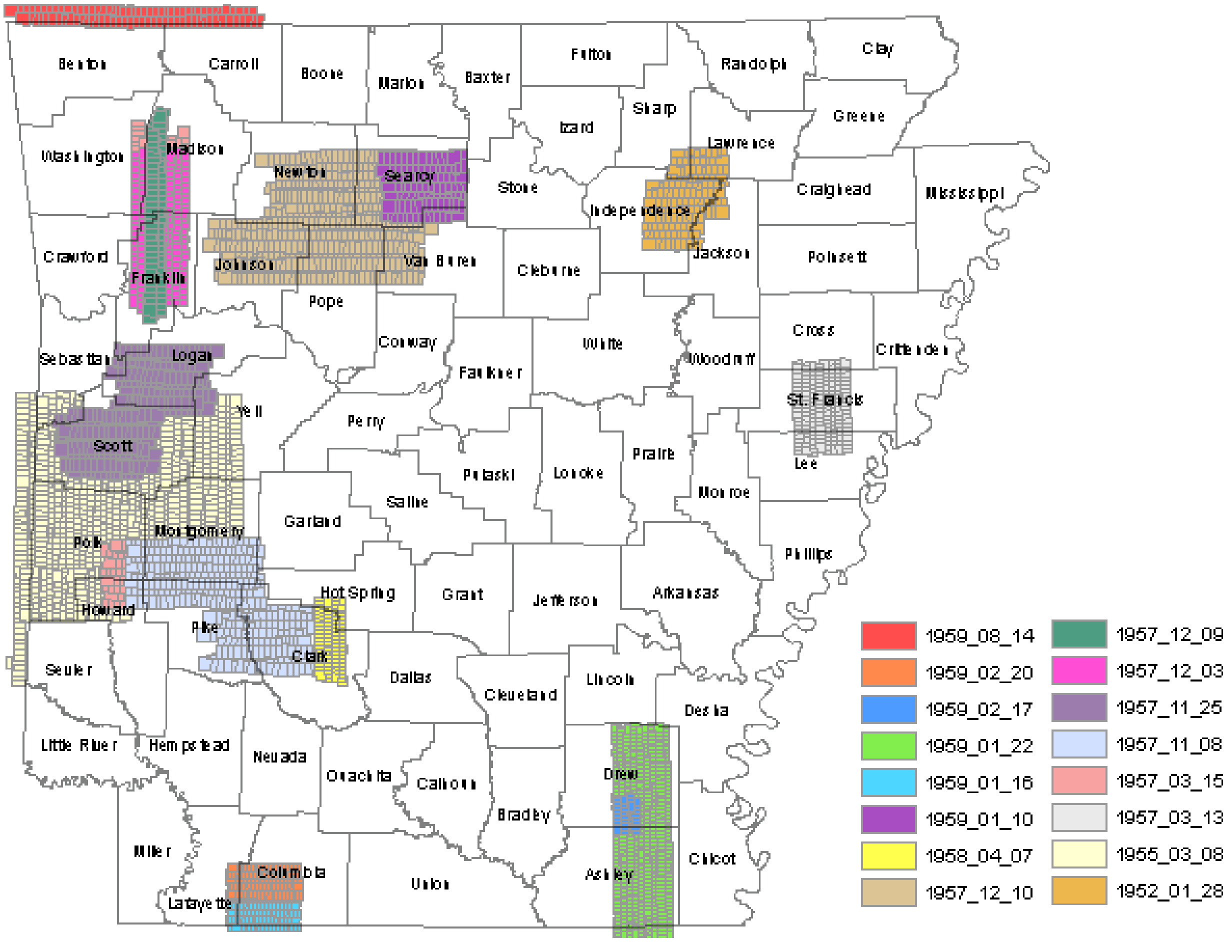
APPENDIX A: EARTH EXPLORER COVERAGE

The following images show the amount of aerial coverage available from EarthExplorer, sorted by year. These are available for viewing and download in various formats on the EarthExplorer website (earthexplorer.usgs.gov). For the images presented here, Aerial Photo Single Frames were selected with scales larger than 1:35,000 and with High Resolution Downloads available, representing relatively ideal images for processing. Although only the results for Arkansas are shown here, this coverage extends into other states and is not exclusive to Arkansas specifically.

1940s Coverage

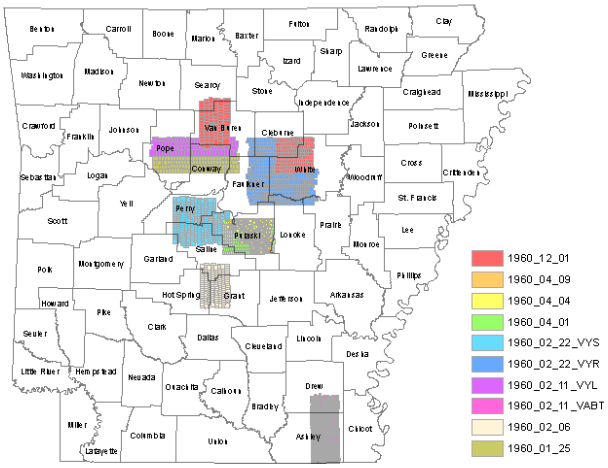


1950s Coverage

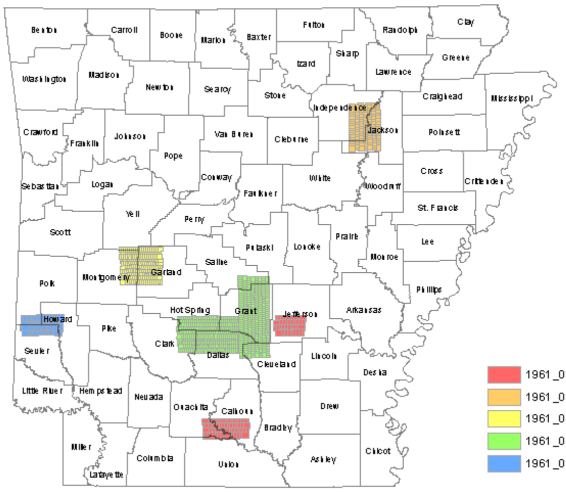


1960s Coverage

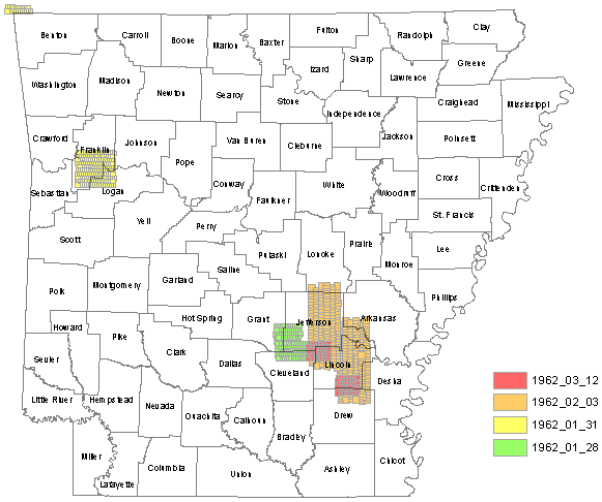
1960



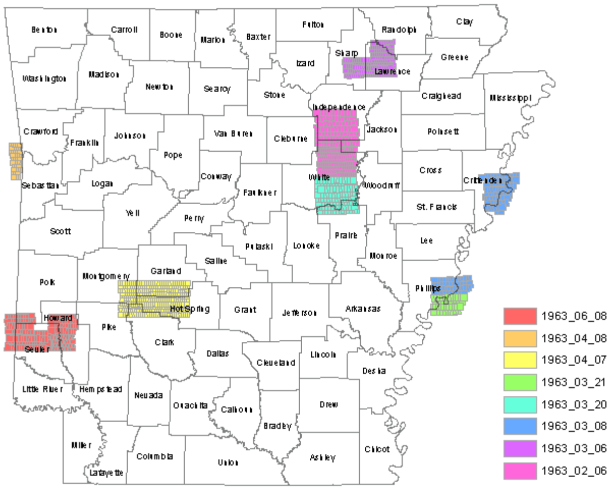
1961



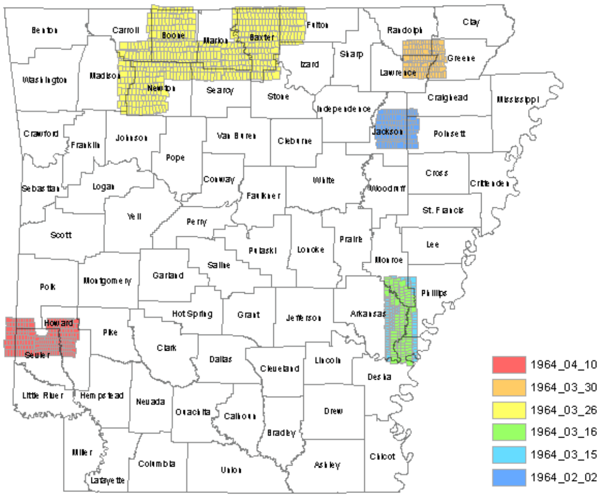
1962



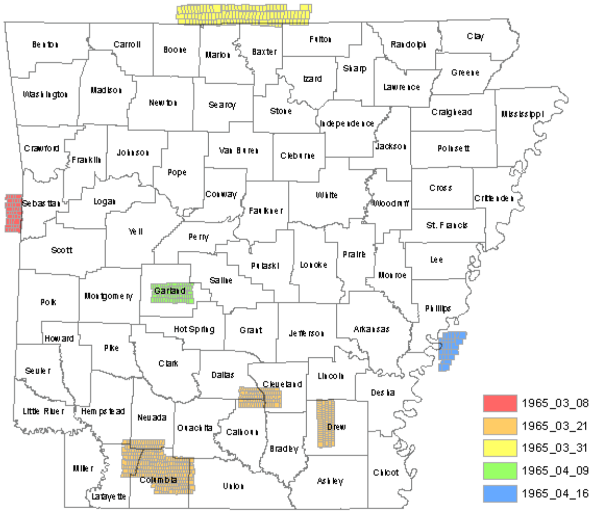
1963



1964

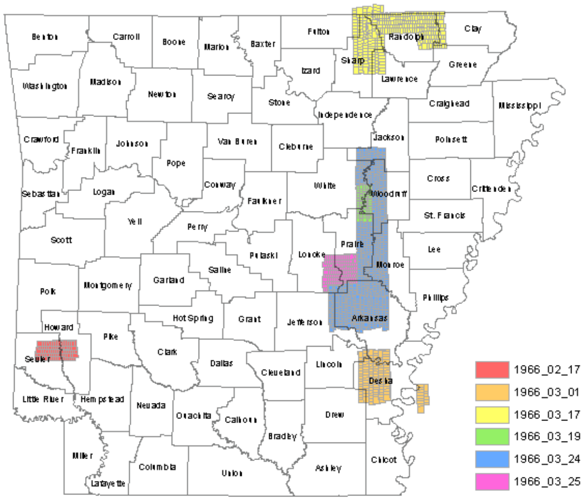


1965

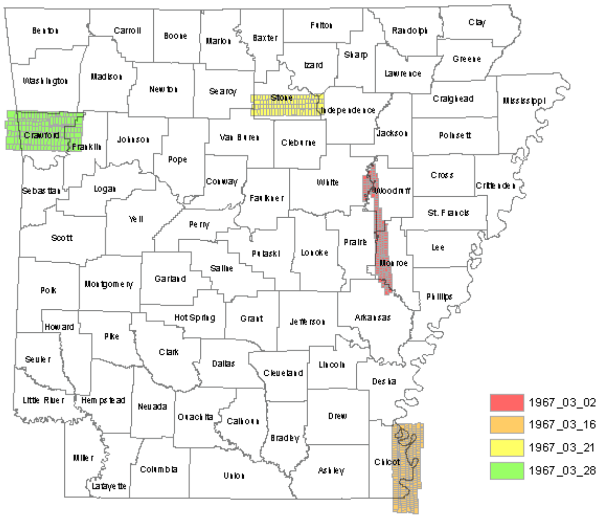


1960s Coverage (ctd.)

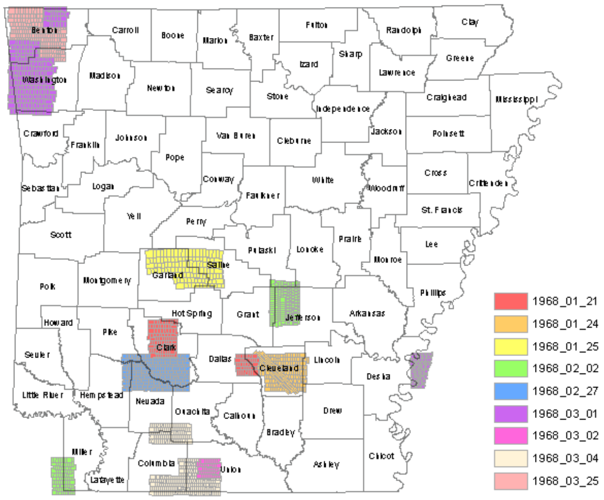
1966



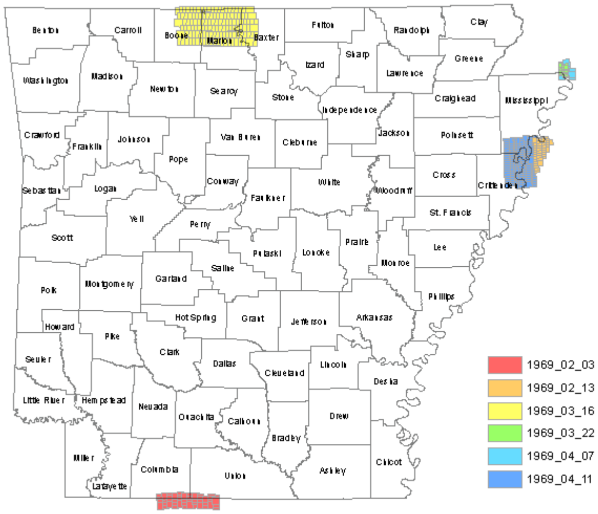
1967



1968

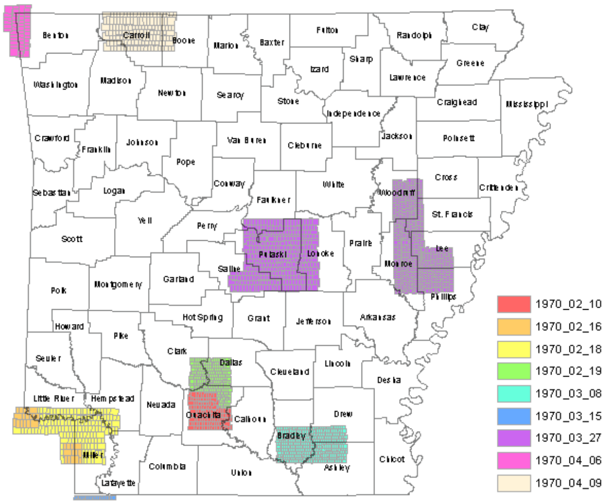


1969

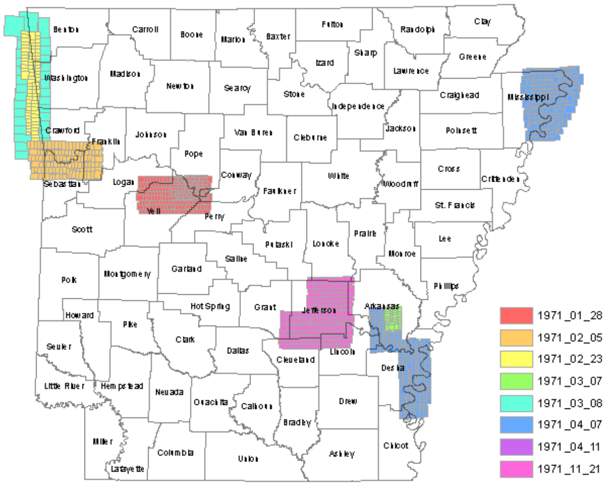


1970s Coverage

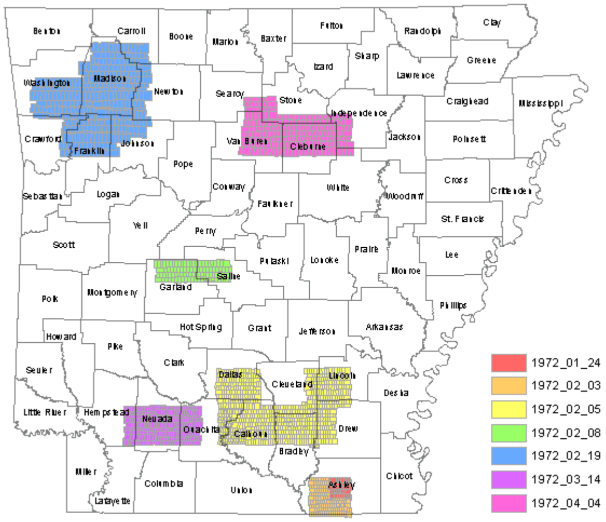
1970



1971

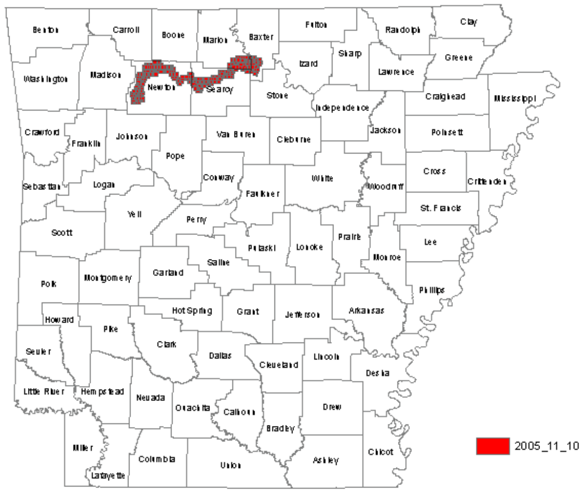


1972



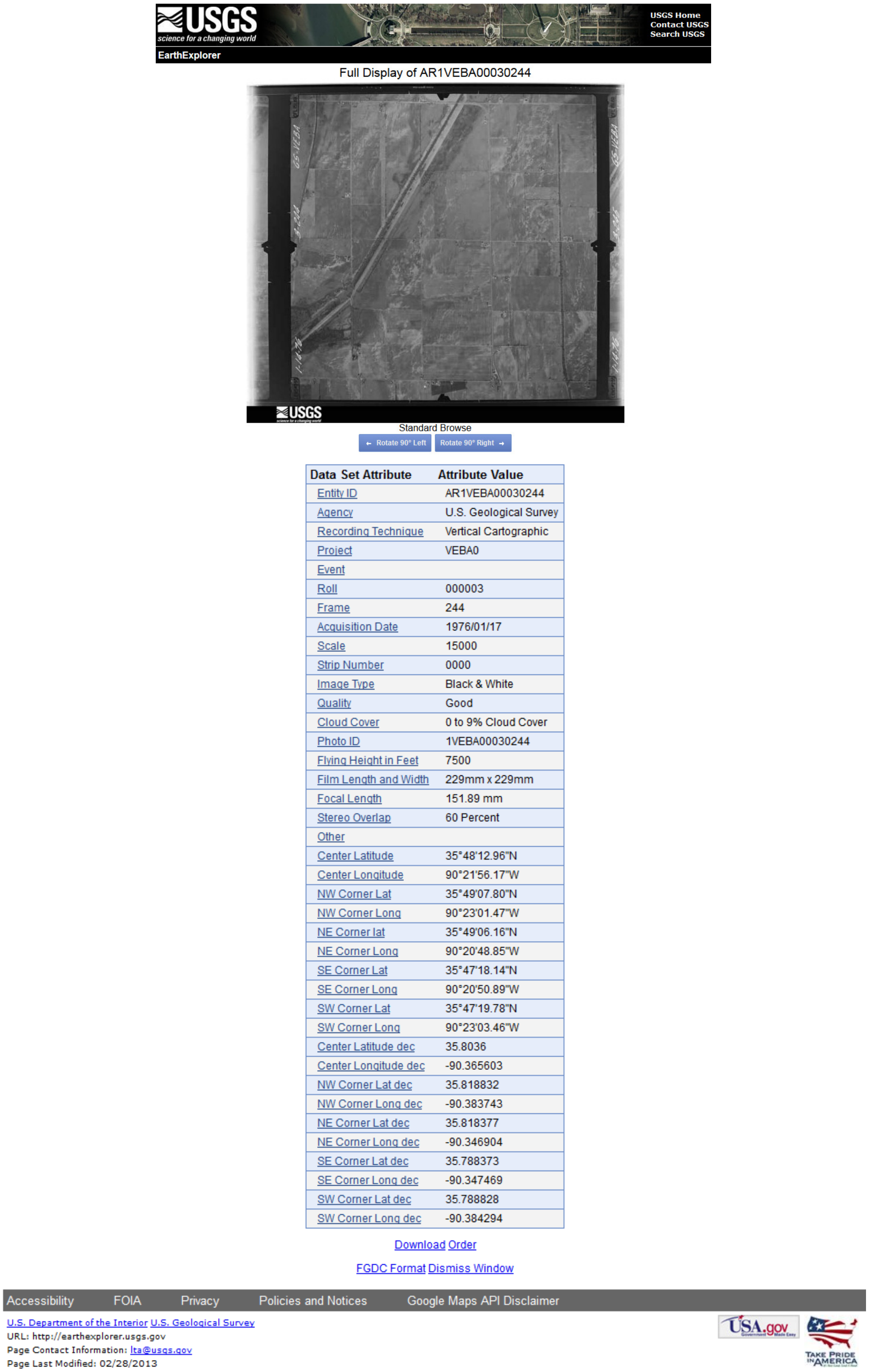
2000s Coverage

2005



2006

APPENDIX B: SAMPLE AERIAL SINGLE FRAME METADATA



Full Display of AR1VEBA00030244

Data Set Attribute	Attribute Value
Entity ID	AR1VEBA00030244
Agency	U.S. Geological Survey
Recording Technique	Vertical Cartographic
Project	VEBA0
Event	
Roll	000003
Frame	244
Acquisition Date	1976/01/17
Scale	15000
Strip Number	0000
Image Type	Black & White
Quality	Good
Cloud Cover	0 to 9% Cloud Cover
Photo ID	1VEBA00030244
Flying Height in Feet	7500
Film Length and Width	229mm x 229mm
Focal Length	151.89 mm
Stereo Overlap	60 Percent
Other	
Center Latitude	35°48'12.96"N
Center Longitude	90°21'56.17"W
NW Corner Lat	35°49'07.80"N
NW Corner Long	90°23'01.47"W
NE Corner lat	35°49'06.16"N
NE Corner Long	90°20'48.85"W
SE Corner Lat	35°47'18.14"N
SE Corner Long	90°20'50.89"W
SW Corner Lat	35°47'19.78"N
SW Corner Long	90°23'03.46"W
Center Latitude dec	35.8036
Center Longitude dec	-90.365603
NW Corner Lat dec	35.818832
NW Corner Long dec	-90.383743
NE Corner Lat dec	35.818377
NE Corner Long dec	-90.346904
SE Corner Lat dec	35.788373
SE Corner Long dec	-90.347469
SW Corner Lat dec	35.788828
SW Corner Long dec	-90.384294

Download Order

FGDC Format Dismiss Window

U.S. Department of the Interior U.S. Geological Survey
URL: http://earthexplorer.usgs.gov
Page Contact Information: lta@usgs.gov
Page Last Modified: 02/28/2013

Example single-frame metadata (http://earthexplorer.usgs.gov/metadata/4660/AR1VEBA00030244/)

APPENDIX C: AMASDA SEARCH QUERY

General Criteria:

Location Reliability: Good

Cultural Affiliation Reliability: Good

Single Artifact = No

Cultural Affiliations Selected (Approximately Late Woodland and Later):

Adams Phase – 186

Afro-American – 140

Anglo-American – 90

Asian – 141

Asian American – 224

Bartholomew Phase – 11

Baytown Period – 12

Baytown, Early – 126

Baytown, Late – 127

Belcher Complex – 207

Bellaire Phase – 13

Belle Meade Complex – 205

Bellevue Focus – 194

Big Lake Phase – 15

Bossier – 222

Botsford – 214

Buckville Phase – 184

Caddo (Prehistoric) – 16

Caddo I – 17

Caddo II – 18

Caddo III – 19

Caddo IV – 20

Caddo V – 21

Caddo, Early – 131

Caddo, Late – 133

Caddo, Middle – 132

Caney Bayou Phase – 22

Carden Bottoms Phase – 193

Caudill Phase – 162

Chakanina Phase – 23

Cherry Valley Phase – 25

Civil War – 91

Coles Creek (Period/Culture) – 26

Contact Period – 27

Contact, Coexistence – 28

Contact, Direct – 29

Contact, Indirect – 30

Contact, Post 1800 AD – 138

Contact, Pre 1800 AD – 137

Contact, Resettlement – 31

Cuesta Phase – 189

Deasonville Phase – 182

Deceiper Phase – 213

Deer Creek Phase – 179

Delaware B Focus – 159

Dunklin Phase – 181

Dutchman’s Garden Phase – 36

East Phase – 211

European – 92

Evans Phase – 151

Fairmont Phase – 183

Field Bayou Phase – 37

Fourche Maline – 39

Fourche Maline, Early – 128

Fourche Maline, Late – 130

Fourche Maline, Middle – 129

French – 95

Friendship Engraved var. Freeman – 209

Ft. Coffee Phase – 154

Glendora Phase – 187

Gober Complex – 208

Gran Marais Phase – 40

Greenbrier Phase – 41

Grove Focus – 161

Habuikut Phase – 156

Haley Phase – 175

Harlan Phase – 152

Hayti Phase – 42

Historic Period – 96

Historic, Other – 139

Hog Lake Complex – 201

Huntsville Phase – 173

Jakie Aggregate – 169

Kent Phase – 43

Koroa (Prehistoric) – 124

Lawhorn Phase – 44

Lawhorn Phase (South) – 45

Little Red River Complex – 203

Loftin Phase – 168

Lost Prairie – 223

Marksville (Period/Culture) – 47

Menard Complex – 204

Mid-Ouachita Phase – 188

Millers Crossing Phase – 176

Mineral Springs Phase – 174

Mississippi Period – 48

Mississippi, Early – 49

Mississippi, Late – 50

Mississippi – 51

Mississippian, Early – 52

Mississippian, Late – 54

Mississippian, Middle – 53

Native American – Historic period – 89

Neeleys Ferry Phase – 177

Neosho Focus – 155

Nodena Phase – 178

Oak Grove Phase – 57

Old Town Phase – 58

Osage (Prehistoric) – 59

Parkin Phase – 63

Pemiscot Bayou Phase – 64

Pemiscot Bayou Phase (South) – 65

Plaquemine Period – 134

Plaquemine, Early – 135

Plaquemine, Late – 136

Plum Bayou Culture – 192

Pomona Focus – 190

Powers Phase – 171

Powers Phase (South) – 65

Prehistoric – 72

Protohistoric, 1400-1650 “hamlets” - 197

Protohistoric, 1400-1650 “lg hunt” – 199

Protohistoric, 1400-1650 “sm hunt” – 199

Protohistoric, 1400-1650 “towns” – 200

Protohistoric, 1400-1650 w/ Spanish – 198

Quapaw (Prehistoric) – 74

Social Hill Phase – 212

Spanish – 107

Spirit Lake Complex – 206

Spiro Phase – 153

Tillar Complex – 196

Transylvania Phase – 180

Turkey Bluff Focus – 163

Walls Phase – 81

Walnut Bend Phase – 195

Wappapello Lake Aggregate – 170

War Eagle Phase – 172

Wilmot Phase – 83

Wilson Phase – 84

Woodland, Late - 88

APPENDIX D: PHOTOSCAN COST AND TIME ESTIMATES

Agisoft PhotoScan: Standard versus Professional

Features	Standard	Professional
Point cloud generation	Yes	Yes
Polygonal model generation	Yes	Yes
Python scripting		Yes
Setting coordinate system		Yes
Orthophoto export		Yes
Digital elevation model export		Yes
Georeferencing of exported models		Yes
Price	$179	$3,499 Stand-Alone License $549 Educational License

http://www.agisoft.ru/products/photoscan/

A Demo version of the Professional version can be downloaded for free. The functions for saving project files and exporting 3D models are disabled, but it does allow one to assess whether the investment will work for specific archaeological datasets and projects. A 30-day trial of PhotoScan Pro is available (http://www.agisoft.ru/products/photoscan/professional/trial/) that has saving and exportation functions enabled.

Computer System Properties for Study:

Windows Edition: Windows 7 Enterprise © 2009 Microsoft

Processor: Intel(R) Core(TM) i7-2600K CPU @ 3.40GHz 3.4 GHz

Installed memory (RAM): 16.0 GB

System: 64-bit Operating System

Example Processing Times:

(1) Extensive Orthoimage and DEM Production (Southwest AR; Dec. 20 1948; 62 photographs)

The following processing times include all steps used in PhotoScan. The time estimates do not include the time that it takes to download the images from EarthExplorer and unzip into a workspace folder. (Note: These processing times are specific to the computer system properties listed above, and will vary depending upon the processing capabilities of the computer.)

Processing Steps (62 Images)	**Time Estimates**
Add images to workspace	<1 minute
Calibrate images	3 minutes
Mask image borders, fiducials, labels	9 minutes (~9 seconds per image)
Align photos (High Accuracy, Generic Pair Preselection, Constrain features by Mask) OR Align photos (Medium Accuracy, Generic Pair Preselection, Constrain features by Mask)	19 minutes 10 minutes
Reorient the Bounding Box	1 minute
Low-Quality Geometry for Placing GCPs (Height field object type; Low target quality, Smooth geometry type; 200,000 face count; 0.1 Filter threshold; 0.1 Hole threshold)	22 minutes
Set Projection	<1 minute
Place and Copy Information for 16 Ground Control Points (GCPs)	~80 minutes (3-10 minutes per point, depending on the difficulty in matching the modern orthoimage to the historic images; ~5 minutes on average for this example)
Optimize GCPs	<1 minute
Low-Quality Geometry with GCPs (Height field object type; Low target quality, Smooth geometry type; 20,000 face count; 0.1 Filter threshold; 0.1 Hole threshold)	26 minutes (*Medium-Quality Geometry takes hours to process for photograph collections of this size. For Medium Quality Geometry, breaking the study areas into smaller chunks and merging them later is advisable.)
Build Texture (Adaptive orthophoto; Texture from all photos; Mosaic blending mode; Atlas width and height at default of 10000 x 20000)	2 minutes
Total Time Estimate	~156 minutes

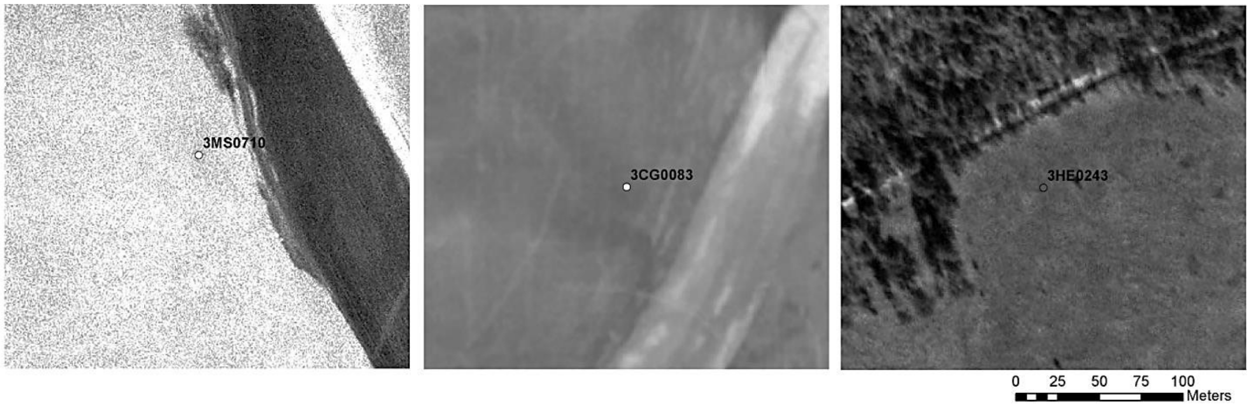
(2) High-resolution Processing of a Stereopair (Sherman Mound; April 7, 1971; 2 photographs)

Again, these processing steps exclude time spent downloading and extracting EarthExplorer images, and specific processing times depend on the computer being used.

Processing Steps (2 Images)	**Time Estimates**
Add images to workspace	<1 minute
Calibrate images	<1 minute
Mask image borders, fiducials, labels	<1 minute (~9 seconds per image)
Align photos (Medium Accuracy, Generic Pair Preselection, Constrain features by Mask)	1 minute (*For this example, High Accuracy setting produces extreme fishbowl curvature)
Reorient the Bounding Box	1 minute
Low-Quality Geometry for Placing GCPs (Height field object type; Low target quality, Smooth geometry type; 20,000 face count; 0.1 Filter threshold; 0.1 Hole threshold)	1 minute
Set Projection	<1 minute
Place and Copy Information for 14 Ground Control Points (GCPs)	56 minutes (~4 minutes on average for this example)
Optimize GCPs	<1 minute
Adjust Bounding Box to Specific Area	1 minute
Ultra-High-Quality Geometry (Height field object type; Ultra-High target quality, Smooth geometry type; 20,000,000 face count; 0.1 Filter threshold; 0.1 Hole threshold)	2 minutes
Texturize	2 minutes
Total Time Estimate	~70 minutes

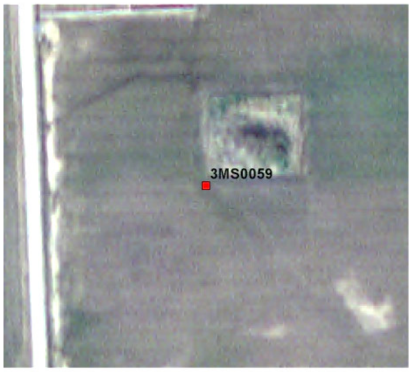
APPENDIX E: EXAMPLES OF INVISIBLE, POSSIBLY VISIBLE, AND VISIBLE SITES

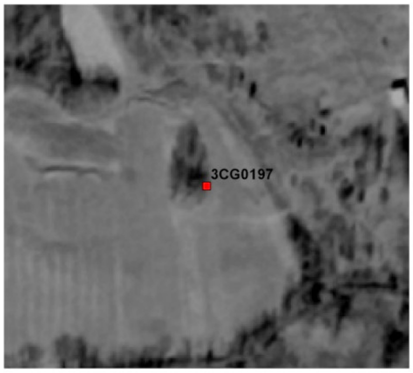
Invisible sites: Either the site shows no distinct change (e.g., color, elevation, shadowing) from the surrounding landscape adjacent to the site center, or such contrasts were interpreted as geomorphological.

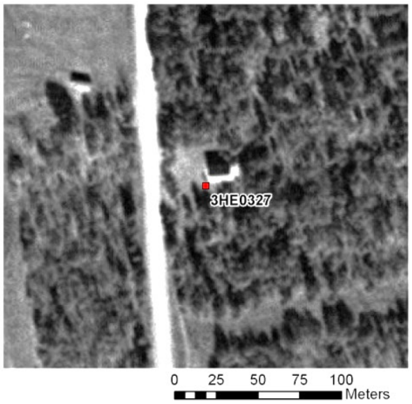


Possibly visible sites: Represents a change from the surrounding landscape, usually as a change in soil color or vegetation. However, they were categorized as undetermined because (1) shape of the landscape anomaly is not immediately recognizable as a manmade structure, (2) the anomaly could be geomorphological, and/or (3) the anomaly could represent relatively modern (post-1900) disturbances to the landscape.

Visible sites: The site represents a distinct change from the surrounding landscape, and it exhibits a shape of a size consistent with building structures or documented built environments. In the case of historic buildings, a structure was clearly apparent in proximity to the recorded site location. Upon follow-up analysis, these sites exhibit features that have been previously documented that correspond with the anomalies.

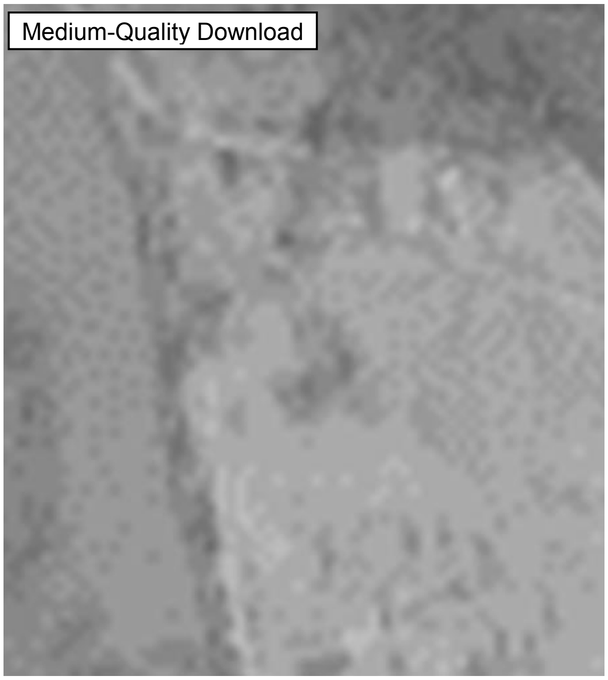




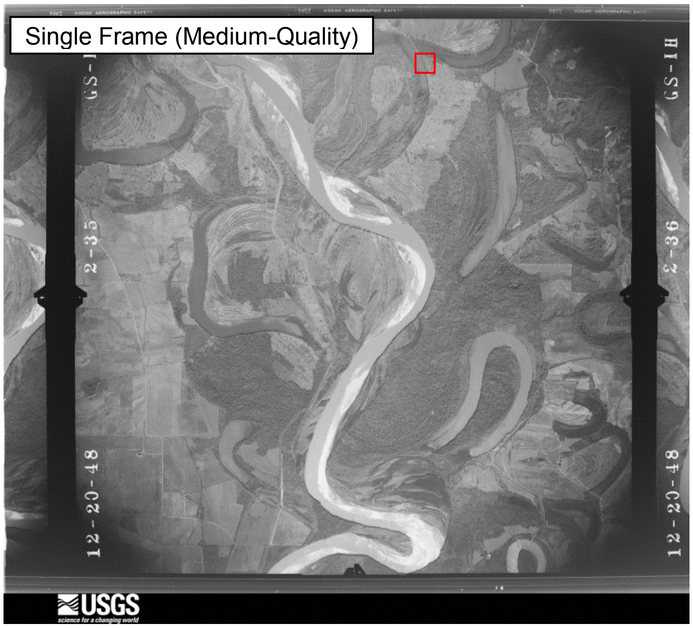


APPENDIX F: COMPARISONS OF IMAGE QUALITY FOR VISIBLE SITES

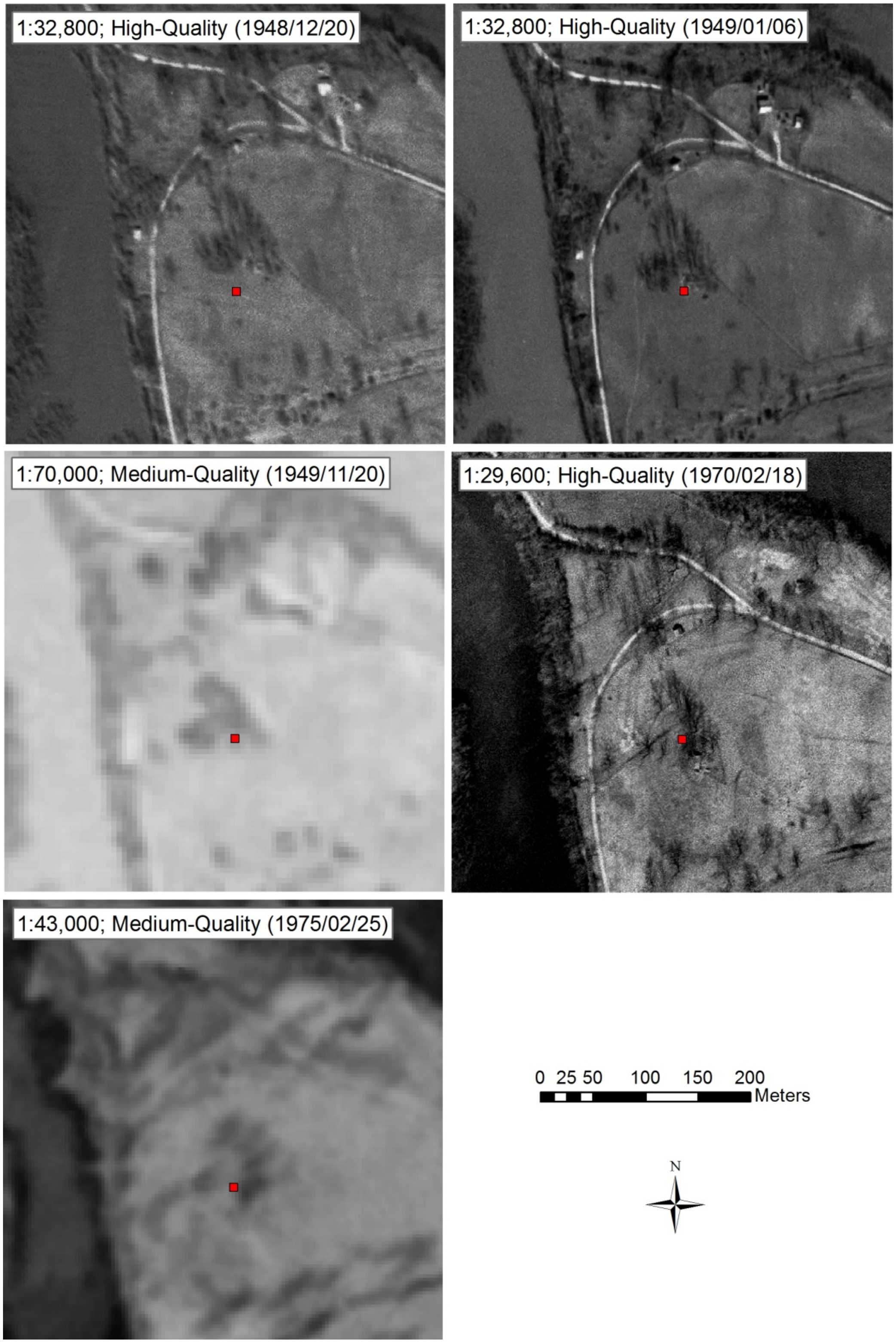
Comparison of Download Resolution (Red Lake Mound, Southwest Hempstead County)


Medium-Quality Download

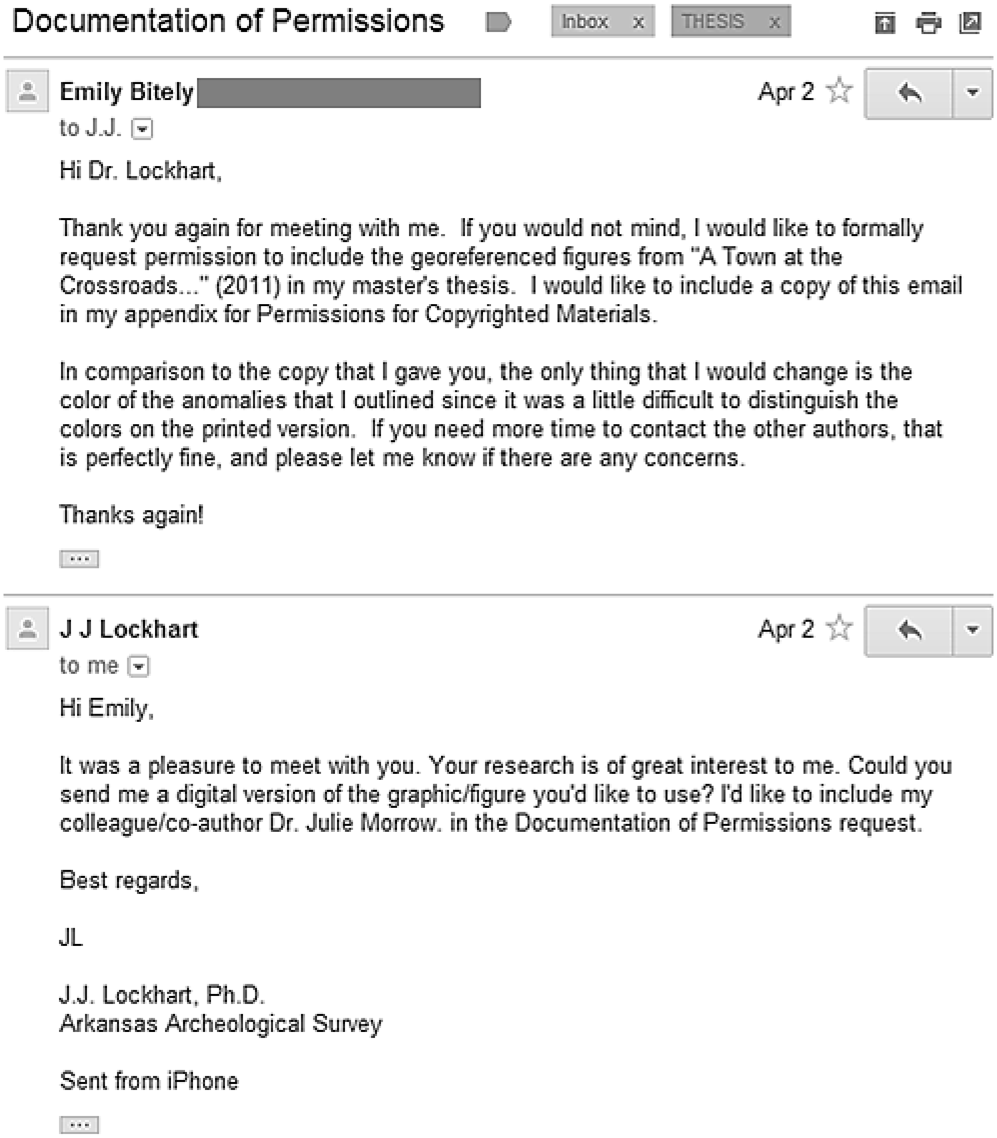

High-Quality Download


Single Frame (Medium-Quality)

Comparison of Geographic Scales (Red Lake Mound, Southwest Hempstead County)



APPENDIX G: PERMISSIONS FOR COPYRIGHTED MATERIALS



Documentation of Permissions

Emily Bitely [redacted]
to J.J.
Apr 2

Hi Dr. Lockhart,

Thank you again for meeting with me. If you would not mind, I would like to formally request permission to include the georeferenced figures from "A Town at the Crossroads..." (2011) in my master's thesis. I would like to include a copy of this email in my appendix for Permissions for Copyrighted Materials.

In comparison to the copy that I gave you, the only thing that I would change is the color of the anomalies that I outlined since it was a little difficult to distinguish the colors on the printed version. If you need more time to contact the other authors, that is perfectly fine, and please let me know if there are any concerns.

Thanks again!

J J Lockhart
to me
Apr 2

Hi Emily,

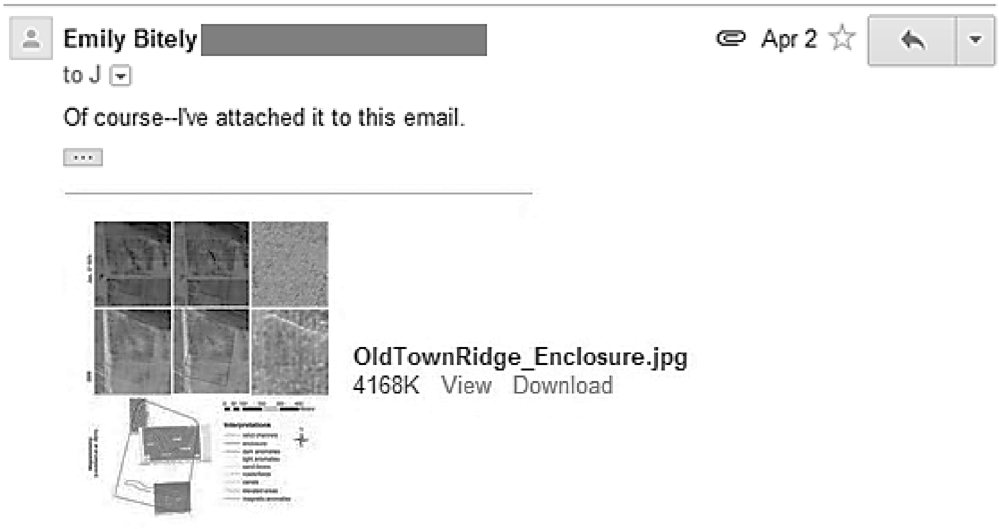
It was a pleasure to meet with you. Your research is of great interest to me. Could you send me a digital version of the graphic/figure you'd like to use? I'd like to include my colleague/co-author Dr. Julie Morrow. in the Documentation of Permissions request.

Best regards,

JL

J.J. Lockhart, Ph.D.
Arkansas Archeological Survey

Sent from iPhone



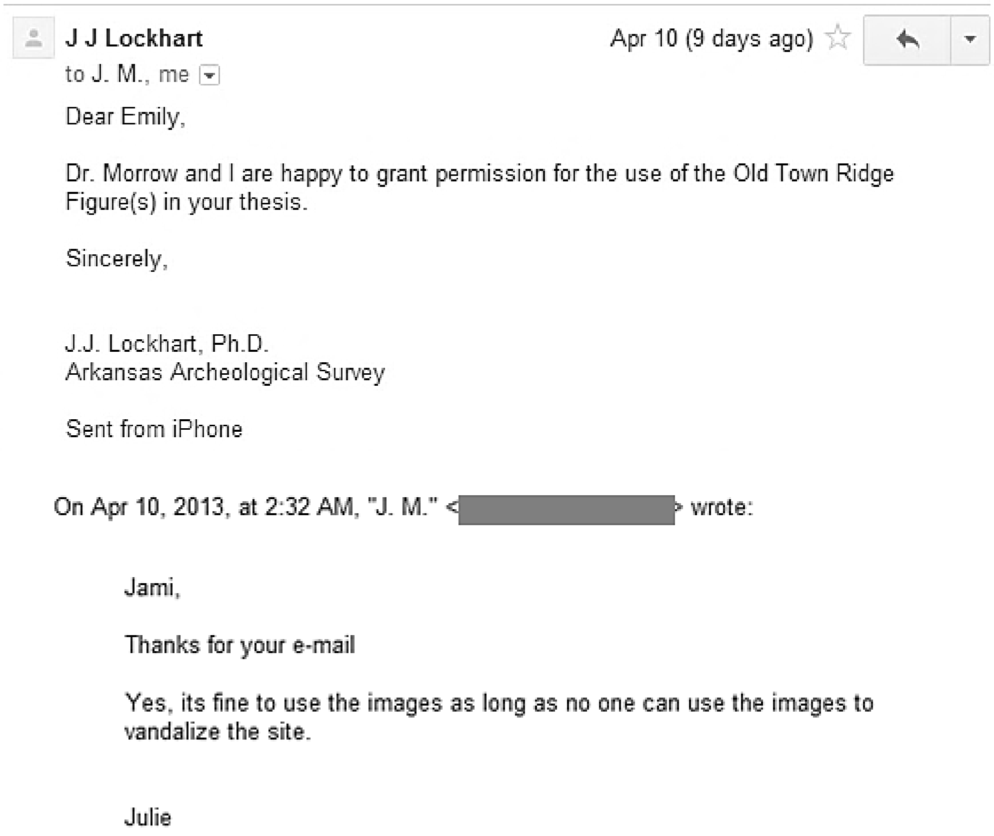
Emily Bitely [redacted] Apr 2

to J

Of course--I've attached it to this email.

OldTownRidge_Enclosure.jpg

4168K



J J Lockhart Apr 10 (9 days ago)

to J. M., me

Dear Emily,

Dr. Morrow and I are happy to grant permission for the use of the Old Town Ridge Figure(s) in your thesis.

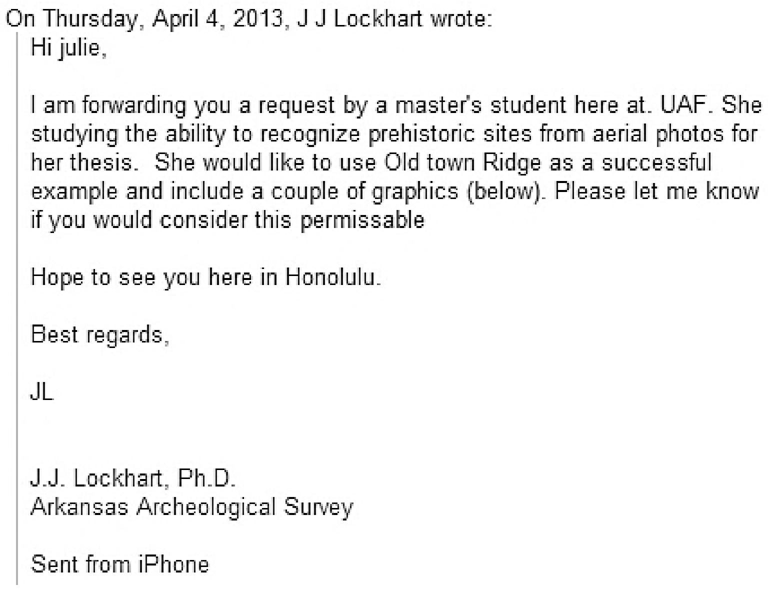
Sincerely,

J.J. Lockhart, Ph.D.
Arkansas Archeological Survey

Sent from iPhone

On Apr 10, 2013, at 2:32 AM, "J. M." <[redacted]> wrote:

> Jami,
>
> Thanks for your e-mail
>
> Yes, its fine to use the images as long as no one can use the images to vandalize the site.
>
> Julie



On Thursday, April 4, 2013, J J Lockhart wrote:

> Hi julie,
>
> I am forwarding you a request by a master's student here at. UAF. She studying the ability to recognize prehistoric sites from aerial photos for her thesis. She would like to use Old town Ridge as a successful example and include a couple of graphics (below). Please let me know if you would consider this permissable
>
> Hope to see you here in Honolulu.
>
> Best regards,
>
> JL
>
> J.J. Lockhart, Ph.D.
> Arkansas Archeological Survey
>
> Sent from iPhone