NEW INTERDISCIPLINARY RESEARCH AT 48PA551: LAND TENURE AND SUBSISTENCE STRATEGIES AMONG MIDDLE HOLOCENE ROCKY MOUNTAIN HUNTER-GATHERERS

By

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ABSTRACT

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This dissertation studies land tenure and resource procurement strategies among Middle Holocene hunter-gatherers in the Greater Yellowstone Ecosystem (GYE). The research provides a better understanding of a stratified archaeological site on the eastern flank of the Yellowstone Plateau, 48PA551, a crucial location for winter resource procurement. Geophysical survey, collection’s research, obsidian sourcing, and stable isotope analysis are all used to test theoretical models of social conditions and hunting strategies during the harsh winters of the mountainous environment of northwest Wyoming. Site 48PA551 has already proven to contain evidence for a unique Middle Archaic adaptive strategy, being one of the only locations in the GYE where housepits have been discovered in a mountainous environment. Overall, this dissertation seeks to highlight the importance of interdisciplinary approaches in archaeological research. The outcomes of this research can be used to influence and inform other fields of science such as wildlife management and ecology. It is the hope that this dissertation reflects the importance of an interdisciplinary approach and identifies tangible outcomes that can be used in other fields of scientific inquiry.

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Chapter 1 - Introduction

The prehistoric occupation of the foothills and mountainous areas of the Greater Yellowstone Ecosystem (GYE) and the Rocky Mountains is no longer up for debate. In recent years, the old archaeological adage that these areas were marginal environments for hunter-gatherers has time and again been picked apart by an ever-growing “mountain” of evidence. The “Mountain Refugium Hypothesis” (Benedict 1975; Benedict and Olson 1978; Husted 1969), which suggested that the Central Rockies were only ephemerally occupied for short durations, has been solidly rejected by investigations across the west. These investigations have proved inhabitation of both high and low elevations at similar rates since at least the Paleoindian period, but especially since the Early Archaic (Aikens 1970; Kornfeld et al. 2010; Larson 1997; Larson and Francis 1997). Given that the refugium hypothesis has been rejected, the last decade or two has seen a shift away from attempts to prove long-term indigenous occupations of these environments to a point where there is now enough data to begin building and testing new theoretical models surrounding the prehistoric indigenous relationship to the Central Rockies. These studies have also affected the management of these resources, which has seen a foundational change in thought surrounding cultural resources of areas now considered the “backcountry.”

This dissertation seeks to test a handful of existing, landscape-sized models using data from a single, well-excavated site, 48PA551. Site 48PA551 has already proven to contain evidence for a unique Middle Archaic adaptive strategy, being one of the only locations in the GYE where housepits have been discovered in a mountainous environment. In addition, the site is unique given the prevalence of mule deer faunal remains that dominate the archaeological assemblage, which is novel in the region. Despite the unique features and novelty of the site, there has been surprisingly little research conducted except for one major report summarizing early excavations of the site (Frison and Walker 1984) and a few smaller reports and conference presentations (Ingbar et al. 1986; Smith 1970; Swenson and York n.d.). Despite being limited, these publications have proven instrumental in creating a baseline of understanding for the Middle Archaic Central Rockies.

The current body of GYE archaeological research has now become robust enough to where differing perspectives of the prehistoric use and tenure of the mountainous region can be tested. In addition to testing existing models, this research seeks to add to the knowledge base of archaeologists and those in other disciplines. Current academic inquiry in the region has become increasingly inter-disciplinary as archaeologists, ecologists, and biologists find intersecting interests and management goals. The common interests of academics and professionals of different fields make the results of model testing that much more impactful. While this dissertation focuses on the archaeological record, there is no doubt that it is heavily influenced by the work of other disciplines, including geology, ecology, climatology, and wildlife biology. However, this influence works both ways, and it is the hope that this body of work joins the growing community of archaeological research that can have major impact on other disciplines.

Many major archaeological studies of mountainous environments have sought to understand these upland areas as prehistorically-inhabited ecosystems, compiling data at a landscape level and broad time scales. The efforts have led to theory-building related to ecological models centered on mountain-dwelling hunter-gatherers. These studies have sought to establish a timeline for high elevation occupations, assess the movement of material culture, and determine land tenure strategies. These broad-scope studies now provide the extraordinary opportunity for researchers to test the landscape scale models with new and revisited datasets from single sites.

This dissertation seeks to do just that and centers on a few simple questions concerning how 48PA551 fits in with these established paradigms.

However, before any hypothesis testing can be undertaken, the results from prior excavations from over 50 years ago must be given context. Only a small number of publications, as mentioned previously, summarize the excavations which unearthed an extraordinary cultural assemblage. While some detailed information exists about the excavations, useful information regarding the spatial provenience of excavated material is almost absent. Some maps, localized excavation coordinates, and a brief synopsis of excavated areas exist, but no central or reliable source ties everything together in a useful manner. Where exactly did previous excavations occur? It may seem like a simple question, but answering it will unlock a huge amount of existing data. Using the pre-existing dataset from UWAR adds a much more robust dataset to the smaller assemblage recovered in 2018. In order to synthesize the two datasets together, photographs, maps, and excavation records from the 1970s are used to provide the spatial context for the assemblage. Using these records, the geophysical survey results can then be used to locate the old, now buried excavation units as well as still unexcavated cultural features. Chapter 4 will discuss the results of the attempt to place the original excavation into context with the most recent investigations. In addition, the chapter will not only be an assessment of geophysical capabilities in the Rocky Mountains but provide a blueprint on how to revive old datasets lacking detailed documentation.

The next question to be addressed in this study is also a simple one; who occupied 48PA551? This question does not seek to determine a specific tribal affiliation with 48PA551. Instead, this question asks if the site’s occupants were composed of a single group of related individuals, multiple family units from a single socio-political group, or un-related groups from different regions who came to the site for hunting and gathering. More specifically, this investigation seeks to understand the regional connections of the site's inhabitants using tool stone sourcing. The substance and organization of the archaeological record hold clues that allow archaeologists to address these types of questions. Specifically, Chapter 5 will utilize obsidian sourcing to trace artifacts to their point of origin. Using toolstone point-of-origin and building off of the large body of literature concerning obsidian conveyance, we can begin to understand how these artifacts and people moved across the landscape to address questions of land tenure and territoriality.

Inherently tied to the question of *who* was there is *what* were they doing there? It is well established that the Middle Archaic hunter-gatherers of the northwestern Plains and the Rocky Mountains (and beyond) was a time of experimentation and innovation. It is now well understood and confirmed by the 2018 excavations that the site is indeed a Middle Archaic, winter-occupied hunting camp that mostly targeted large game. Mule deer (*Odocoileus* hemionus) were by far the most numerous big game species harvested at the site. However, the specific hunting strategies are not well understood. Clues from the faunal assemblage point to appendicular and axial skeletal elements, suggesting hunting was occurring both locally and in areas that required some travel and transport. Chapter 6 demonstrates the use of stable isotope analysis on a subset of the mule deer to assess how mule deer were spread across the landscape using isotopic values to see whether they were locally harvested or transported from beyond the local area. Additionally, isotopic values can be used to determine whether the deer were taken over time (attritional kill events) and harvested or if they were harvested in large groups at one time, suggesting a mass kill event like a drive or a trap. The degree of variation in strontium, carbon, and oxygen isotopic signatures can differentiate these various hunting strategies.

Overall, this dissertation seeks to highlight the importance of interdisciplinary approaches in archaeological research. Archaeological research is tied to other research in the world of natural resources. The outcomes of archaeological research can be used to influence and inform other fields of science such as wildlife management and ecology. Archaeological research can be informed and influenced by these disciplines just the same. It is the hope that this dissertation reflects the importance of an interdisciplinary approach and identifies tangible outcomes that can be used in other fields of scientific inquiry. By incorporating data from an indigenous, prehistoric archaeological site, we can better understand public land and wildlife management issues in the modern world.

Chapter 2 - Environmental and Cultural Background: Archaeology of the Middle Archaic, Paleoclimate, and Findings from 48PA551

The region of focus in this study stretches across Montana, Idaho, and Wyoming on lands managed by a diverse group of federal, state, tribal, municipal, and private land stewards, in ecosystems just as diverse as the groups who manage them (NPS 2022). The ecosystems of northwestern Wyoming (and northeastern Idaho and southwest Montana) are characterized mainly by vegetation and altitudinal zones (Hughes 2003: 36). The lower regions, such as the semi-arid Bighorn Basin, are dominated by sagebrush vegetative communities from 1000-1750 m, with less than 10 inches of rain a year. This zone is home to warmer summers and average winter temperatures and has the region's most frost-free days, playing host to sage-dependent species, especially sage grouse (*Centrocercus urophasianus*) and mule deer. The basin sagebrush community gives way to mountain foothills, which transitions to expanded grasslands around 1750 m. Mixed in with the grasses, stands of juniper (*Juniperus* spp.) and fir appear between 1800-2400 m with slightly cooler annual temperatures and increased moisture. Lodgepole pine (*Pinus contorta*) forests take over once one climbs out of the previous vegetative zone and remain up to at least 2600 m. Before the tree line, the final forested zone is dominated by forested communities of subalpine fir (*Abies lasiocarpa*) and spruce (*Picea* spp.) followed by white bark pine (*Pinus albicaulis*) at the highest edge (2800 m). The resilient white bark pine communities give way to alpine meadows and tundra above 2800 m, where winter can last until July.

The Greater Yellowstone Ecosystem is a hotbed for archaeological research, stretching back to some of the first major investigations at Mummy Cave in the 1960s (Wedel, Husted, and Moss 1968; Husted and Edgar 2002). Most early investigations focused on the major well-known sites at lower elevations which produced some of the few excavated, stratified sites that we know today. Given that a relatively small number of sites have been thoroughly excavated, archaeologists have relied on surface sites to fill in the rest of the picture. Between compliance work and formal research, surface recordings continue to build larger datasets that have brought archaeologists deeper into the backcountry and higher up the slopes. In recent years, high elevation and backcountry archaeology has increased in popularity. At times, this work is completed out of necessity to deal with the effects of climate change as archaeological sites are exposed from receding ice patches above the treeline.

Environmental and Cultural Records of the Middle Holocene 5700-3200 BP

Across the continent, the Middle Archaic appears to have been a time of emergent socio-cultural diversity. The first sedentary village societies in the Pacific Northwest appeared around 5500 years ago (Chatters 1995; Lepofsky et al. 2009), approximately around the same time as complex mound builders in the Southeastern United States (see Kidder 2011; Sassaman 2011; Saunders et al. 2005). The Middle Archaic/McKean complex across the Plains saw a shift towards new subsistence patterns, with a greater reliance on gathering and processing, as evident from increased frequencies of groundstone (Cassells 1983, Greiser 1980; Kornfeld et al. 2010). However, also during this time on the plains, bison procurement strategies seemingly diversified (Frison 1978; Wormington and Forbis 1965). It was even suggested that early traces of agriculture appeared at this time in Central High Plains (Irwin-Williams and Irwin 1966). Regardless of the region, experimentation and shifting subsistence or settlement strategies is well documented during this time period across the continent. Given the location of the central Rocky Mountains and known cultural interactions to the east and west (Gibson 2001; Rousseau 2004), it would not come as a surprise if emergent cultural complexity appeared during the same time in the central Rocky Mountains. Middle Archaic archaeology in this region has been subject to the ebbs and flows of research trends, as all topics are, and as of this writing, it is currently out of fashion. However, this was not the case in the 1980s and 1990s, when the Middle Holocene was a hot topic given the booming natural resource extraction industries, especially in Wyoming.

Much of the literature concerning the Middle Archaic was produced between the 1950s (when the McKean type site was excavated [Mulloy 1954]) and the late 1980s/early 1990s. Diverse sites ranging from small temporary camps to potentially densely occupied villages are found across a broad range of environments from the high plains and desert basins to mountain environments (Kornfeld et al. 2010; Larson and Francis 1997; Mulloy 1954). Like many cultural complexes, this period is typified by a distinct set of projectile points, but even those reflect the diversity of the time ranging from lanceolate shapes to notched and eared projectiles. Four routinely recovered points from Middle Archaic sites include the Hanna, Duncan, Mallory, and McKean Lanceolate projectiles (Kornfeld et al. 2010). Initial interpretations of these artifacts suggested that they represented socio-ethnic differences at these sites, but more recently, the diversity can mostly be explained as subtle technological changes over time (Kornfeld et al. 2010). Given the cultural diversity of this time, the origins of the Middle Archaic, specifically the McKean Complex, are still relatively unknown and subject to debate. Early interpretations suggest that the complex descended from the Archaic Desert cultures of the Great Basin (Jennings 1964; Reeves 1983; Wedel 1961). Others link the McKean complex as a direct descendant of the Foothill-Mountain Paleoindian complex recognized in the Central and Southern Rockies, given evidence from Mummy Cave (Husted 1969) and elsewhere (Benedict 1981). The continuation of small semi-subterranean pithouses from the Early Archaic to the Middle Archaic suggests a continuation of cultural practices and subsistence strategies, especially in the desert southwestern part of Wyoming (Kornfeld et al. 2010; Larson 1997; Larson and Francis 1997; Smith 2003). The pithouses have been interpreted as winter base camps, especially given the evidence of storing food that was likely collected in the spring and summer. 48PA551 reflects this strategy but still remains the only site containing pithouses in the Central Rocky Mountains.

Pithouses or housepits were first recognized as semi-subterranean structures during the investigations at the Shoreline site (48CR122) which was discovered eroding out the shoreline of Seminoe Reservoir in the 1970s (Walker and Zeimens 1976). Following this recognition, other sites with similar shallow, bowl shaped stain features were reinterpreted as pithouses, which was the case at 48PA551. Following this discovery, more and more structures were discovered especially in southern and southwestern Wyoming as the structures were discovered during the excavation of pipeline trenches (see site 48SW1029 [Hobbs and Garcia 1981]). Since then, pithouses have been discovered in the northwestern Plains and Rocky Mountains from northern Colorado to Southern Wyoming (Kornfeld et al. 2010; Larson 1997; Larson and Francis 1997; Smith 2003). Most structures are small and average between two and six meters in diameter at sites with one to thirteen houses and are found at shallow depths (Kornfeld et al. 2010; Waitkus and Eckles 1997). However, no housepit has yet been discovered from surface evidence and all have been located from ground-disturbing activities (such as trenching), erosion or through remote sensing. The age range of these structures date back to the Early Archaic (8000 BP) and continue through the Late Prehistoric Period (post 1500 BP) (Kornfeld et al. 2010). Most radiocarbon dates from housepits are from the Early Archaic and is the first appearance of the settlement adaptation in the region (Harrel, Hoefer, and McKern 1997).

Most evidence points to housepits being occupied during colder weather and winter months, as reflected by botanical and faunal data (Kornfeld et al. 2010; Larson and Francis 1997). Given the winter occupation of these structures, many houses contain internal pit features such as hearths or storage pits where seeds, roots, tubers, and faunal remains were stored (Rose 2008). However, housepits are generally devoid of large quantities of cultural material but excavations mostly reflect a desert Archaic way of life, similar to adaptations established in the Great Basin (Kornfeld et al. 2010). The cultural remains usually included some groundstone (though site furniture is limited) and evidence for seed or vegetable processing. Faunal remains include a whole range of species from rodents, rabbits, and upland bird species to deer, elk (*Cervus canadensis*), and bison (*Bison bison*). However, large game was never the focus at most sites (Kornfeld et al. 2010).

While 48PA551 reflects some of the same traits as these other housepit sites across Wyoming, it doesn't quite fit the desert-Archaic adaptation model. First of all, the site is found over 6000 feet above sea level within a mountainous, forested environment and remains the only housepit site to be located within such an environment. Part of the reason for the unique location may just be a product of the lack of ground-disturbing activities in these environments. While much compliance work occurs on National Forest managed land, most is limited to surface survey without subsurface testing. The massive infrastructure development in the sage-steppe basins of central and southern Wyoming from the oil and gas industry has led to far more subsurface disturbance and data recovery excavation. However, the obvious focus on large game at 48PA551 suggests that there was indeed something unique happening at the site. The Middle Archaic occupations at the site may represent a unique continuation of the Early Archaic housepit adaptation. Given similar Middle Archaic housepits in the nearby Bighorn Basin (such as the Spiro site [Walker-Kuntz et al. 2006]), northern Wyoming may represent the northernmost extent of the settlement strategy. It is likely that other housepits or structures may exist in montane environments and these investigations at 48PA551 may provide clues to help locate similar sites.

While it is important to discuss the Middle Archaic as a whole, it has been illustrated that there is some recognizable variability between the Central Rocky Mountains and the Northwestern Plains (Page 2017). This is especially important given the location of 48PA551, nestled into the mountains of northwest Wyoming. The radiocarbon record reflects population trends that point to differences between western Wyoming and the Central Rockies, despite well-known overall decreases in population during the latter half of the Middle Archaic (post 3700 BP). For example, populations in the Central Rockies appear to have declined earlier than some basins (Big Horn Basin and Wind River Basin) and western Wyoming around 4500-4300 BP (Page 2017). The Central Rockies then rebounded during times of decreased moisture while western Wyoming and some of the basins experienced population decline post-3700 B.P. This likely is the result of harsher basin conditions from the lack of moisture (decreased precipitation measured at Lake of the Woods (Shuman et al. 2010, Shuman 2012). Page (2017) suggests that the increase in the Rockies may have been due to population growth in established groups and survival rates but could also reflect immigration, increased occupational duration, or intensification of upland use.

In addition to the cultural history of the Middle Holocene and Central Rockies, a significant effort has been made to understand the dynamic ecological history of the region through paleoenvironmental records (Spanbauer et al. 2018). Yellowstone Lake was the focus of initial studies in the 1980s since it has been accumulating layers of sediment since the end of the last ice age, which contain physical and biological components that offer a comprehensive record of past environmental conditions (Spanbauer et al. 2018). Studies in the region have focused on temperature estimates (Shuman 2012) by studying fossil pollen profiles, soils as environmental proxy (Huckleberry 1985; Reider et al. 1988), moisture reconstructions (Pribyl and Shuman 2014; Shuman et al. 2010), and multi-proxy approaches to environmental reconstruction including geochemistry, mineralogy, diatoms, and stable isotopes (Jacobs and Whitlock 2008; Whitlock et al. 2012) to study the nuanced environmental history of the northern Rocky Mountains. This aggregation of paleoclimatic data is of great importance to the studies of hunter-gatherers who have inhabited the area in the past and whose descendants continue to live in the immediate area. Studying the ecological conditions allows for the consideration of the landscape in which prehistoric peoples found themselves. The implications from the ecology at the time of site occupation help archaeologists understand the archaeological record, given that the conditions around them shaped the cultural material left behind. However, understanding these conditions can also be used to address the impact that prehistoric peoples had on the ecological landscape, not just the other way around. There has been growing interest in how people adapted to landscapes during times of environmental change and the ecological impact that humans have always had on their surroundings. Studies such as these may dramatically impact how land managers approach decision-making in modern times.

48PA551 is on a low creek terrace along Dead Indian Creek in a valley bottom at the edge of the Sunlight Basin in northwest Wyoming. The site sits at approximately 6,100 feet above sea level (1,860 meters) in the flat valley bottom. The site extends on the west and eastern terraces of the creek, but the majority of archaeological investigations have occurred on the eastern terrace. Currently, the local environment consists of a subalpine fir and lodgepole pine community and includes a riparian zone near the creek. The terrace is covered by sage brush and low grasses with sparsely scattered conifers. The lowest terrace below the site contains moderately dense coniferous and deciduous trees similar to the steep slope that serves as the site’s eastern boundary. When attempting to place an archaeological site in the ecological context in which it was created, a few questions can arise that can be addressed by the paleoecology studies mentioned above.

First of all, it is important to understand what plant communities occupied the project area during the human occupation. This foundational question needs to be understood before moving on to any more specific question about the environmental context of this site. The plant community of any given region is determined by a number of factors, including temperature, moisture, and soil formation processes. The studies mentioned at the beginning of this section include fossil pollen and soil studies which can be used as a proxy to create a holistic picture of the environment at the time. Knowing which plant communities occupied the area lends insight into not only temperature, precipitation, etc., but can also be used to make inferences about tree line, available forage for both humans and wildlife, available shelter, fuel for fire, relative fire activity in the general vicinity, and more. Given the expanded radiocarbon record from the most recent rounds of investigations and the few radiocarbon dates from the initial investigations, we can confidently place the occupation of the site in a specific time during the middle Holocene.

Understanding the Middle Holocene environment is also important to know why it was so attractive to hunter-gatherers. This question stems directly from the first question about plant communities and is at the heart of this study. Given the extensive archaeological deposits at 48PA551, there was obviously a major attraction to this particular area and the ecosystem inhabited and exploited by its residents. What exactly was so attractive? The implications from understanding the plant communities in the area can directly tie to why hunter-gatherers chose to stay in this area during the winter months.

What about the local ecology made it so productive for cervids? This third question also grows out of the questions raised above. The original and most current excavations at 48PA551 revealed a remarkable quantity of cervid remains, mainly mule deer, with an MNI of greater than 50 individual mule deer alone (Frison and Walker 1984). Given this apparent preference for mule deer and the large numbers of harvest, we hope to see how and why the paleoecology of the area supported such a productive population of ungulates.

Finally, can the modern ecological context serve as a proxy for interpretations of the site? This question is slightly different than the others and seeks to see if we can use the modern environment as an analog for the paleoenvironment for archaeological interpretation. How different was ecology from that of today? If the ecological differences are negligible, it is much easier to interpret the archaeological record and the subsistence strategies of those who originally occupied the site.

An early study by Waddington and Wright (1974) sought to examine late quaternary vegetation changes in the eastern part of Yellowstone National Park (YNP) in connection with the archaeological investigations at Mummy Cave (Wedel et al. 1968). The study sampled cores from a bog pond (Cub Creek Pond) 10 km west of Sylvan Pass and four kilometers east of Yellowstone Lake (Waddington and Wright 1974). The coring effort was to find a clear-cut pollen sequence that could provide a basis for inferring regional vegetational changes. The subsequent pollen sequence spanned about 15,000 years of regional history. The early pollen sequence indicated that the region had been dominated by alpine vegetation between the period of deglaciation (14,360 BP) and 11,500 BP, meaning a spruce and fir parkland covered the

Yellowstone Plateau. After that time, the pollen indicates a quick shift to a mosaic of spruce, fir, whitebark pine, and lodgepole pine, indicating a warmer climate than the previous period. This pattern continued and culminated in the Altithermal, dated to 9000-4500 BP in this study, where lodgepole pine most likely dominated the entire Yellowstone Plateau. The study did not have the capacity to include any more nuanced interpretations of the pollen record. However, the authors did conclude that the Altithermal interval most likely did not affect the Mummy Cave area at a lower elevation, given that the area most likely stayed forested despite sagebrush steppe extending farther onto mountain flanks. This suggestion may have implications for 48PA551 given its similar location in a low valley (around 2000 masl) next to a significant water source. Although Dead Indian Creek is not as large of a waterbody as the North Fork of the Shoshone River, the same sort of "cold sink" effect could have kept the area immediately surrounding the site forested despite the effects of the Altithermal. The implications of its position would mean that the area immediately surrounding 48PA551 would not have experienced much change throughout its history and remained heavily forested.

A 1988 study by Reider et al. examined soil evidence for forest and grassland fluctuations in northwestern Wyoming. Soils from the western side of Dead Indian Pass along Wyoming State Highway 296 were studied. This pass sits directly above the archaeological site at the center of this study. The purpose of the study was to gain paleoenvironmental insights into the region by studying soil morphology and phytoliths. The soil morphology indicated that the soil formation during the Althithermal period at the pass formed under grassland conditions, especially on the sunny slopes. However, evidence points to a rapid shift to forest expansion during climatic changes at the end of the Altithermal and the transition into what the authors refer to as a neoglacial or return to post-glacial climates (Reider et al. 1988: 192). The authors also examined phytoliths to examine environmental change. The basic principle here is that opal phytoliths persist in the soil for millennia and that plants that are leaf-dominated (e.g. grasses) produce a much greater amount of phytoliths than stem-dominated plants such as trees (Rovner 1971). The shape of the cells recovered from the phytoliths can be used to estimate former vegetation and compare it to what is discovered in the modern context. The study found that the deeper soil (from the Altithermal) contained phytoliths indicating widespread grassland conditions, while the more recent soil deposits contained much less evidence for grass vegetation indicating a change to moister conditions allowing for the expansion of dense forest (Reider et al. 1988: 194).

Two additional soil morphology studies (Eckles et al. 1992; Huckleberry 1985) specifically focus on the deposition at 48PA551, which contribute essential data to the paleoecology study of the site. Huckleberry (1985) identifies an apparent shift from dry (Altithermal) conditions to moister conditions during the middle Holocene. This study identifies the older, Altithermal soils as comparable to what is found in the Big Horn Basin. This soil formation stems from what would have been dry conditions with calcareous parent material, leading to significant calcification of the older soils (Huckleberry 1985: 105; Reider et al. 1984). Huckleberry identifies a significant difference in the calcification between the younger and older soil horizons at 48PA551, suggesting a drastic climate shift. The Medithermal soils continued to contain some calcification in areas that were not forested, but podzolic soil is found consistently throughout the site indicating significant forest cover. Eckerle (1992) conducted geoarchaeological testing at the site during limited test excavations nearby in 1988. Eckerle identified a depositional unit that was deposited due to increased aridity during the Altithermal time period. He postulates that the vegetation zones most likely moved upwards, resulting in the replacement of post-glacial forest with grassland and shrubbery (Baker 1976; Eckerle 1992: 30; Mehringer 1985). The study then notes an erosion event that truncated this arid deposition which was followed by new soil formation due to increased effective precipitation that corresponds to the Neoglacial. The valley turned from an active deposition area to an actively downcutting channel at this junction. As the Altithermal fill began to be removed, vegetation coverage increased. The downcutting event occurred between 5500 and 4300 BP. It is thought that then the tree line began to lower and that both the slopes and the riparian area around the site would have increased in browse that would be favored by deer and mountain sheep populations (Baker 1976; Mehringer 1985; Redier et al. 1988; Reeves and Dormarr 1972).

Adding to these archaeological focused studies of the paleoenvironment, more recent investigations add finer detail to the past plant communities, temperatures, precipitation, and fire activity of the broader GYE (Whitlock 1993; Whitlock et al. 2012). Whitlock et al. (2012) outline multiple proxy data findings from Crevice Lake (1684 masl, approximately 60 miles straight line from 48PA551), a small body of water in northern Yellowstone National Park. The lake’s 9400-year-old record provides a better understand the environmental history of the Holocene in the northern Rockies. Lines of evidence included pollen, charcoal, geochemistry, mineralogy, diatoms, and stable isotopes. Results from the lake cores were broken down into Early, Middle, and Late Holocene interpretations. The Middle Holocene interpretations provided a level of detail that has not yet been discussed in this section on paleoecological conditions. Overall, it appears that during the Middle Holocene, the season of highest precipitation shifted from the winter to the spring. Given the wet springs, there is a correlation with high fire activity during the summers resulting from the fine fuel development (Whitlock et al. 2012: 101). Specifically, the authors point to charcoal evidence at Crevice Lake and Blacktail Pond, showing a decrease in fire activity between 7000 and 5000 BP followed by a rise to more fire frequency between 5000 and 4000 BP due to the phenomenon described above. Slough Creek Lake also shows a trend towards more fires during the middle Holocene (Millspaugh et al. 2004). The Crevice Lake data implies that as the middle Holocene winters became much drier, springs became longer and wetter, and summers were warm, though with a general cooling trend until 4000 BP. However, there was a notable period between 5600 and 5000 BP where there were very short springs and warm, dry summers, according to the diatom data (Whitlock et al. 2012: 100).

The general long-term climate patterns of the region have been recognized for some time (Shuman 2010; Shuman et al. 2012). At the end of the Pleistocene, the ice cap sitting over the GYE began to shrink and begin a deglaciation period. The climate patterns at this time are known to have been cold and harsh until about 9,000 BP. During this time in the early Holocene, it is widely accepted that a period of rapid warming occurred typified by dry, arid conditions called the Althithermal. This period persisted to more or less until 6,000 BP, and during that time, the vegetation became much more open, coinciding with widespread, regional drought (Reckin 2018). The onset of the middle Holocene is typified by rising lake levels, wetter winter conditions, and cooler summers. This is the start of a long-term climate pattern seeing dry winters and cooler summers, especially in the last 3,000 years. However, this general trend has been broken throughout the last three millennia, with drought cycles occurring during the Roman Warm Period (2,000 BP) and the Medieval Climatic Anomaly (1,200-800 BP). Also anomalous to the longer-term trend, the Little Ice Age (700 BP) brought longer winters and springs along with short summers.

The studies of paleoecological conditions described above provide crucial context for archaeological interpretations at 48PA551. Using the findings from these studies, we can begin to address the questions outlined at the beginning of this section. First of all, there appears to be some disagreement between authors of these studies about when Neoglacial conditions returned during the middle Holocene. Overall, it likely occurred somewhere between 6000-4500 BP. Radiocarbon dates from 48PA551 place the occupations within this period where these studies point to expanding forests and a lowering treeline. The riparian area around the site would have also expanded, providing more browse for big game species such as mountain sheep and mule deer. Macrobotanical analysis at 48PA551 (discussed later in this chapter) recovered possible fire fuel remains of *Abies* spp., which supports the presence of denser fir forests rather than a grassland/sage steppe ecosystem. Starch analysis on groundstone and fire cracked rock (FCR) (also discussed later) places a significant number of geophytes in the area of the site as well. The results from this analysis tie specific plants directly to the archaeological occupation, unlike the rest of the paleoecology studies. This approach looks at the plant community through the lens of gathering activities identifying plants that were specifically introduced to archaeological features for fuel or food. We have some insight into the plant community at the site but still are left speculating about the rest of the plant community. Pollen samples from pond/lake cores in the region describe the immediate surroundings of the specific water bodies and do not directly correlate with 48PA551.

The area was most likely attractive to hunter-gatherers for a variety of reasons. First and foremost, the diversity of available food items must have made this area popular for humans in the middle Holocene. The macrobotanical and starch analyses indicate there were a wide variety of edible geophytes in the area that humans most likely utilized. The cervid remains at the site are widely discussed in reference to the site's function, but less attention is paid to edible plant material. Even if hunting was the focus of this site, a diet cannot only consist of red meat meaning that the local plant community must also be exploited for direct consumption (Speth and Spielman 1983). The expanded forest and riparian habitat made this area a haven for big game during the winter, making it a place where hunter-gatherers would situate themselves. Mule deer in this area migrate from the high country down to valley bottoms during the late fall/winter to search for available browse during the snow-covered months before leaving again in the spring. These migrating patterns indicate that browse for mule deer must have been readily available in the middle Holocene, given the large faunal assemblage.

In addition to subsistence, shelter from winter elements most likely made this local ecosystem desirable. The evidence for denser forests and a lower treeline most likely means that the site was more heavily forested than today. The narrow valley already provides some shelter given the "rain shadow" effect noted by Huckleberry (1985) created by the ridgeline to the west. Expanded forests in this area would have provided more shelter for hunter-gatherers living there both within and outside of housepits. The area would have a steady supply of fuel for heating and cooking activities, backed by charcoal from Douglas-Fir in the botanical analysis.

The studies discussed previously show that the ecology near 48PA551 was actually quite variable, despite long-term climate trends. Although the area continues to house the same flora and fauna as it did in the middle Holocene, we can be fairly certain that the landscape looked different than it did today. The area was most likely much more forested than the present open grass and sage-covered terrace bordered by trees. The riparian area was more expanded than it is today, unaffected by the modern anthropogenic impact of roads, trails, and campgrounds. However, modern ecology can still be used to contextualize the archaeological record given the remaining similarities. The modern mule deer population can be studied to understand how the herds move through the area during different seasons as a baseline for understanding past cervid behavior.

Lake and pond coring studies (Reider et al. 1988; Whitlock et al. 2012) have extraordinary value to archaeological studies and to some degree, can recreate the prehistoric landscape to situate the archaeological record. In the GYE, it appears that these studies show a high level of diversity in results and show that the paleoecological record is much more variable and should be examined on a location-by-location basis, despite long term and broader trends. Fine-grained environmental records of hyper-local contexts are crucial for better understanding sites such as 48PA551, which was occupied during a time of both cultural and environmental transition. A much more localized study is needed to truly understand the paleoecological conditions in this narrow valley adjacent to the Sunlight Basin.

A Brief History of 48PA551 (1969-1989)

Site 48PA551 was originally dubbed the “Dead Indian Creek” site due to its location near a creek, hill, pass, gulch, meadow, ranch, etc., of the same name. The name results from a story following a conflict between the Nez Perce and the U.S. Army and is described in the National Register for Historic Places form (Junge 1973). The U.S. Army engaged in conflict with the Nez Perce near a fort at DeMaris Springs, who pursued them towards the pass separating the Sunlight Basin from the Bighorn Basin. A native scout, positioned on top of a hill, could be seen by the American soldiers who halted their pursuit to prepare for another skirmish. However, the attack never came, and the Nez Perce sentinel was positioned in the same place, seemingly unmoved by the following day. The U.S. Army then realized that the “scout” was a deceased member of the Nez Perce, killed in the skirmish at DeMaris springs, who was placed there as a decoy to deter the Army’s advance. Thus, the name “Dead Indian” was unfortunately used as a place name for the area in which these events took place. However, I will from use only the site’s Smithsonian trinomial to reference the site due to the insensitive nature of the original name.

Site 48PA551 was a winter-occupied hunting or base camp located on terraces along Dead Indian Creek, directly adjacent to the Sunlight Basin of northwestern Wyoming. The site is situated in the foothills of the Absaroka Mountains in the Clarks Fork of the Yellowstone River drainage basin that separates the Absaroka Mountains from the Beartooth Mountains. Early investigations were initiated following avocational archaeologists’ visits in 1967. Vernon Drake, an architect from Billings, Montana, brought the site to the attention of the United States Forest Service (USFS) after discovering a large amount of debitage, bone, and exposed thermal features in the creek banks near an established campground. Drake speculated that this site was likely on an old Indian trail that connected with the known trail that follows the Clark’s Fork of the Yellowstone River. Following these findings, formal testing of the site was conducted in three field seasons in 1969, 1971, and 1972 by the local chapter of the Wyoming Archaeological Society (WAS) with the support and guidance of Dr. George Frison of the University of Wyoming.

Five areas of the site were excavated during these investigations, and the bulk of the cultural material recovered came from the 1972 field season. Cultural deposits were extensive, including 565 complete or fragmentary projectile points, 259 other chipped stone tools, 55 groundstone artifacts, the partial remains of a sub-adult human, and an extensive faunal assemblage dominated by mule deer (MNI=50) and, to a lesser extent, mountain sheep (MNI=16). The faunal assemblage also included a smaller number of big game remains, including elk, bison, pronghorn (*Antilocarpa americana*), black bear (*Ursus americanus*), and various small mammals and birds. In addition to the artifact assemblage, 42 thermal features were uncovered, varying in morphology and interpreted function. Another feature of interest was a peculiar basin-shaped pit that contained a circular arrangement of male mule deer skull caps with antler still attached. Finally, a housepit was discovered in a soil profile containing organically rich, dark sediment in addition to thermal and pit features, though originally it was interpreted as an old stream channel. From various features at the site, three radiocarbon dates were recovered dating to 3800 ± 110 B.P., 4180 ± 250 B.P., and 4430 ± 250 B.P., squarely placing this site in the Middle Archaic. In 1974, the site was listed on the National Register of Historic Places. The cultural assemblage from these original investigations was analyzed at the University of Wyoming, mostly by students, and the findings were eventually synthesized in a dedicated issue of the Wyoming Archaeologist (Frison and Walker 1984).

Following these early investigations, further but more limited testing was conducted by the Office of the Wyoming State Archaeologist in 1985 as a result of road and bridge modification. These investigations occurred farther north or downstream of the previously mentioned excavations. Though much more limited in scope, the testing in 1985 revealed a more complex stratigraphic profile which provided evidence of continual occupation from the Early Archaic through Late Prehistoric time periods. A radiocarbon date of 5470 ± 130 B.P. was recovered from this sequence as well as diagnostic artifacts indicating the longer, continual occupation. Finally, in 1989 a sole test unit was excavated by the US Forest Service within the Dead Indian Creek campground, slightly farther downstream from the bridge but no cultural material was recovered.

University of Montana Investigations 2017-Present

In recent years, the Shoshone National Forest expressed concern about the condition of the site stemming from both natural and human impacts. The site’s location along a major tributary of the Clarks Fork of the Yellowstone in the Absaroka Mountains means that the drainage experiences severe and violent seasonal runoff from snowmelt. Years of runoff and potentially the disturbance from the early investigations have led to further cutbank erosion. Site visits confirmed that cultural material was indeed exposed and was actively eroding into the water, including lithic material, animal bone, FCR, and charcoal. Given the exposed cultural material and the site’s proximity to an active campground and busy road, the USFS also expressed concern about the loss of archaeological materials to collectors and visitors at the site. The USFS reached out to Dr. Anna Prentiss at the University of Montana with these concerns and discussed the possibility of revisiting the site with more modern theoretical and methodological investigative frameworks to recover data before they were lost. A research plan was developed to include multiple phases of investigation. The first phase was to utilize geophysical equipment to identify cultural features. The second phase would ground truth geophysical anomalies through test excavation, while the third phase would include larger block excavations influenced by the tested anomalies.

Phase one was completed in 2017, followed by the second phase in 2018 (summarized in Prentiss 2019; Prentiss et al. 2017). No excavation occurred during the 2017 field session, and instead, a reference grid was established for geophysical survey and excavation. Magnetic gradiometer data was collected to identify cultural features in the subsurface. In 2018, ground-penetrating radar data was collected in the same grids to better understand the subsurface and provide locations for focused excavations of cultural features.

Geophysical data were collected over a 4,550 square meter area across the archaeological site, where cultural material was known, and in areas where no archaeological materials were visible. The magnetic gradiometer results revealed a number of anomalies along the cutback, where the bulk of the cultural material has been identified. However, the magnetic data provided a much higher magnetic range of potential prehistoric features, upwards of 100 nanoteslas (nT). Despite the bright background noise (likely originating from rock of volcanic origin), fifteen potential cultural anomalies were identified during the magnetic gradiometer survey (Sheriff 2017). Seven of the anomalies were interpreted as probable cultural features and marked for excavation, while the remaining eight were anomalies of interest, but their origin was unknown. Six grids of radar data were collected along the eastern bank of the creek, overlapping with areas identified in the magnetic data as having high potential for cultural deposits. The radar data confirmed a number of magnetic anomalies in addition to identifying features that were not located in the gradiometer data. A more detailed analysis of the geophysical results is presented in Chapter 4.

Limited test excavation of geophysical anomalies was conducted by a University of Montana field school, revealing an abundance of cultural material. Excavations were conducted in three major areas but included a few outlying units that tested the findings of the geophysical survey. Most excavations focused on cultural deposits identified near the site datum at the center of the site and exposed cultural material along the cutbank. A third but smaller excavation area was located on the northern edge of the site, testing a larger feature identified in the magnetic data. Six square meters were excavated across 24 unit quadrants (50x50 cm).

Six features were discovered during the course of excavation, including four thermal features with remnant charcoal and the remains of two housepits, distinct from the housepit found during the original excavations. The thermal features were shallow pits or hearths that likely represent sustained heating and food processing areas. The two housepit features that were discovered, one near the datum and the other along the cutbank, are shallow, bowl-like forms filled with dark black sediments (Figure 2.1). The sediments contained a variety of cultural materials, including lithics, faunal remains, and fire-cracked rock. The housepit nearest to the datum appears to have been excavated into cobble-filled sediments and is thicker than the thin dark lens found in the cutbank. The thin profile of the cutbank housepit may just represent the margin of the structure and may thicken towards the middle.

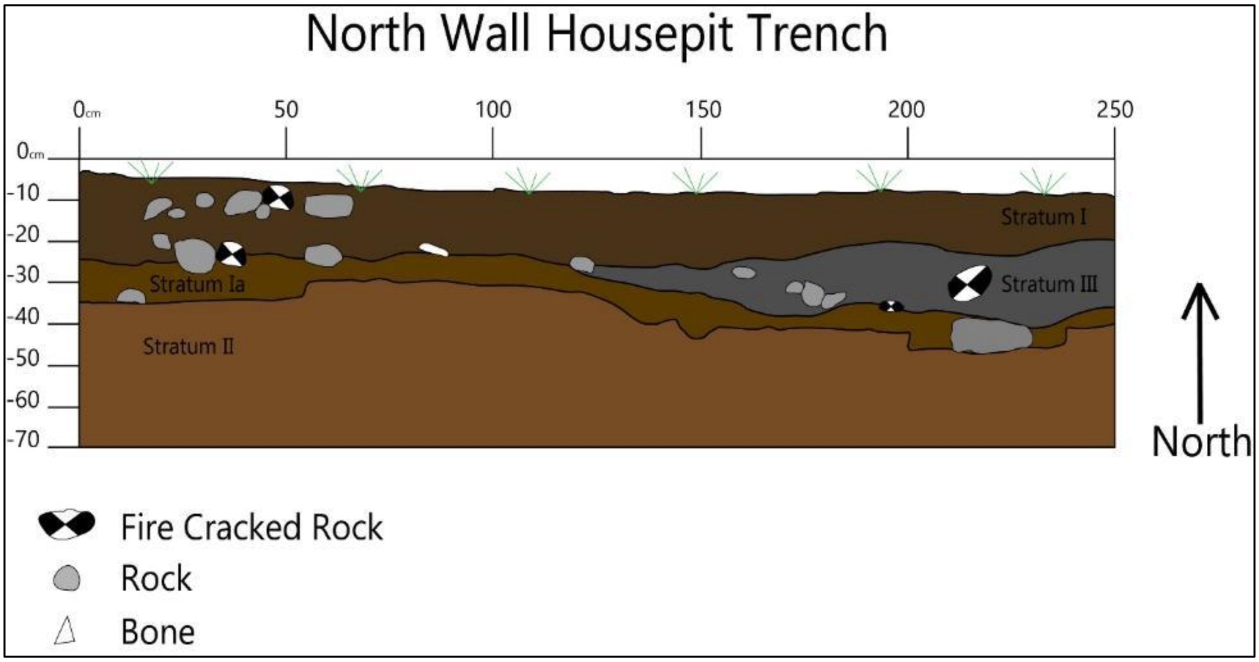


Figure 2.1. Profile of datum area housepit. Stratum III represents housepit fill.

Ten radiocarbon dates were obtained to assess and confirm the original dating of the Middle Archaic occupations and address the possibility of multiple occupations at the site. Charcoal was dated from three features and both of the housepits in addition to three mammalian bones. Most of the results cluster around ca. 4500 cal. B.P. but include one outlier at ca. 5000-5500 cal. B.P., which confirms the original dating of the site. Initial Bayesian modeling of dated material clusters in three places along flat or "reversal" points in the calibration curve (Figure 2.2). This initial assessment suggests that there may be three distinct occupation periods. The housepit nearest to the datum falls at ca. 4300-4500 cal. B.P. A handful of thermal features, the cutbank housepit, and bones from cutbank deposits cluster at ca. 4500-4800 cal. B.P. Finally, the site's northern portion returned an older date at ca. 5100-5400 cal. B.P. These dated materials in these clusters reflect spatial variability across the site, indicating "horizontal" stratigraphy from repeat occupations at different areas of the site, including some overlap. Vertical artifact dispersal may result from variable sedimentation from cut and fill events from stream channels and gravel bars. The vertical deposition of the site warrants further research.

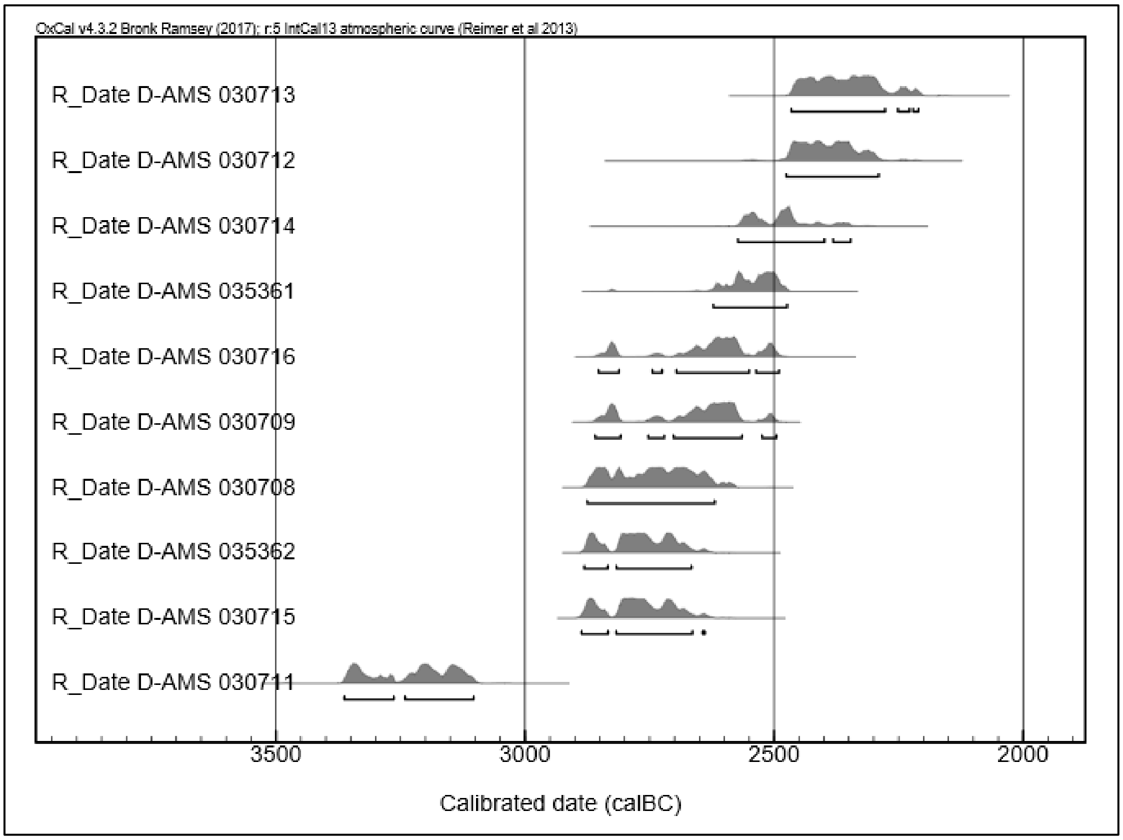


Figure 2.2. OxCal (Version 4.3) plot of calibrated and modeled radiocarbon dates from 48PA551 (from Prentiss 2019).

The 2018 excavations, though limited, revealed a large number of lithic artifacts similar to those recovered during the original excavations. The lithic assemblage is dominated by bifaces, projectile points, and groundstone, reflective of many McKean occupations across the west (Figure 2.3). However, tool types were considerably diverse beyond these three major categories. Initial analysis of the tool and debitage assemblage reflects a hybridized occupational pattern between winter mobility and sedentism (Prentiss 2019). Cores appear to have been transported to the site to use as toolstone for expedient tool creation, suggesting preparation for lack of access to toolstone during the winter occupation. The dominance of bifaces and projectiles from diverse raw materials suggests that late-stage bifaces or finished products were brought to the site and maintained for hunting big game (lack of evidence for early-stage reduction). Finally, groundstone artifacts were made from locally available material to be used for geophyte and other food processing (ethnobotanical evidence presented later in this chapter). This assemblage, and the lack of evidence for tool or toolstone stockpiling, implies that hunter-gatherers were indeed practicing winter time sedentism. This site represents a strategy of logistical organization where they could target big game but still have access to other stockpiled foods. The lithic assemblage of groundstone and a hunting/butchering toolkit reflects winter time preparation in order to maximize resource procurement.

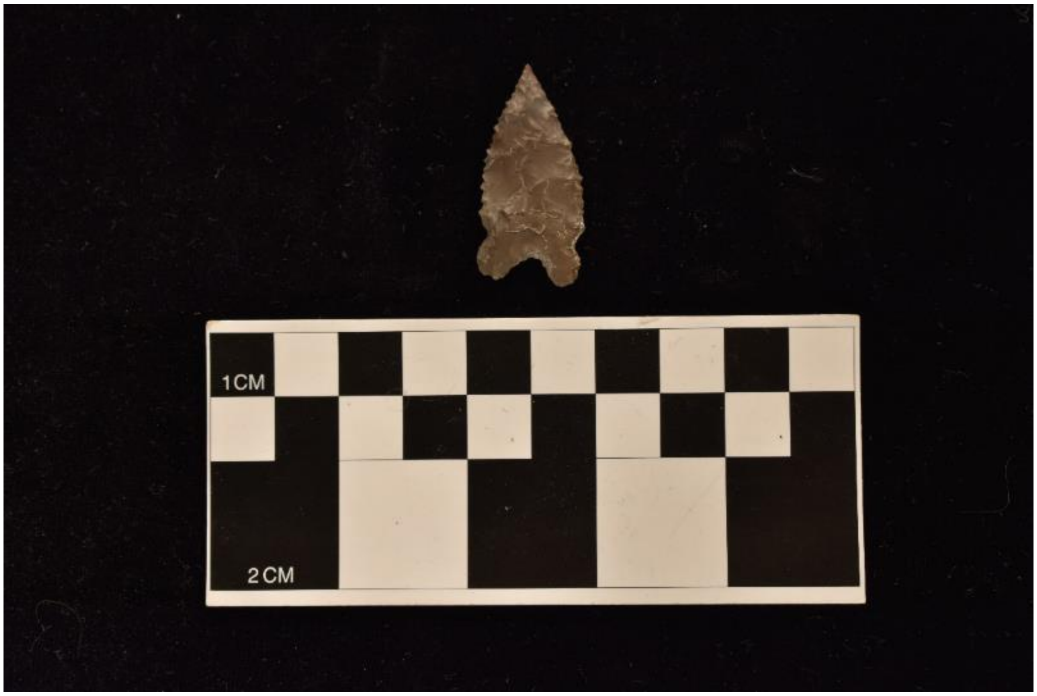


Figure 2.3. Example of Middle Archaic projectile recovered during 2018 excavations.

The faunal assemblage recovered in 2018 was much smaller than the original excavations but reflected the findings outlined in Frison and Walker (1984). Both appendicular and axial elements were present, but there is a clear emphasis on limb components, given that most of the identifiable elements were appendicular cervid remains. Recovered remains were highly fragmentary, which beyond taphonomic processes suggests that some level of bone processing was occurring. Processing is especially evident along the cutbank, where the highest density of bone was found both intact and fragmentary, including a considerable amount of burned bone (see Thurman 2021 for detailed discussion of cutbank bone bed). The extent of bone processing (though cut marks were rare, perhaps due to small sample size) tracks with the lithic findings, suggesting semi-sedentary, winter-seasonal occupation of the site. The emphasis on cervid remains also tracks with the dominance of bifaces and projectiles, pointing again to the logistical positioning on the landscape to target large game. Of particular interest was an apparent cervid bone bed located along the cutbank. Many intact cervid long bones were located in this area, in addition to two bone tools (awls or needles).

Macrobotanical and starch grain analyses were performed on sediment and FCR recovered from the 2018 excavations. Many plant remains from features related to fuel, supporting the inferred functions of the features as thermal features such as hearths and roasting pits. However, some dietary botanical remains were recovered, including burned fragments of Polygonaceae, *Balsamorhiza sp.,* and *Chenopodium* sp. seeds. However, the quantity of these remains were few due to the limited excavation and therefore did not provide compelling evidence about low-ranked seed gathering and processing. However, starch grain analysis conducted on five groundstone artifacts and five FCR fragments revealed a consistent appearance of starch grains from geophytes. Geophytes that could include *Calocleartus* (Sego Lilly), *Apiaceae* (*Lomatium* [biscuit root]), *Erythronium* (Yellow Avalanche Lilly), and *Claytonia* (Spring beauty) were all noted in the starch grain analysis. The implication here is that harvesting, roasting, and grinding these starchy roots and tubers could have played a role in balancing the diet at 48PA551, explaining the number of groundstone artifacts.

Despite the success of the 2017 and 2018 field seasons, the most recent excavations only targeted a very small portion of the site. These investigations provided much better and more modern radiocarbon dates but lacked the quantity of cultural material recovered from early excavations. Given the small dataset, it was determined that any interpretations from this dissertation must include data from the original excavations. Including the original provides a much more robust sample size of mule deer and obsidian specimens and provides the general spatial context for the original excavated material. Fortunately, the Frison Institute provided two different rounds of funding to visit the University of Wyoming Archaeological Repository

(UWAR) and analyze specimens recovered from their collection. The following is a brief synopsis of the collection's research, the findings, and the state of the collection.

Collections Research at UWAR

In February 2020, I was able to visit the University of Wyoming Archaeological Repository (UWAR) to curate the 2018 materials and examine the originally excavated collection. This trip and the subsequent analysis of collected specimens were funded by the Frison Institute at the University of Wyoming. Previous collections research of site 48PA551 was conducted by Dr. Lawrence Todd and Dr. Rachel Reckin concerning the projectile point assemblage from the original excavation. This research included photographing and measuring all projectiles and sourcing the obsidian points included in the dataset (obsidian results presented at SAA 2019 conference and included in this dissertation). However, besides the projectile points and some faunal remains, the entire assemblage remained uncatalogued at the time of the 2020 visit. The assemblage is located throughout the facility in various states of organization and analysis. For example, mule deer skull caps from a feature in the original investigation were located in a cardboard box with no lid, while an additional collection of projectile points were located in Dr. George Frison's office. Lithic tools and certain faunal skeletal elements (maxillae and mandibles) were organized and partially labeled based on initial analysis, and an incomplete faunal database was discovered on a floppy disk. A handful of photographs from the field and laboratory were discovered, in addition to a small handful of incomplete, poorly scanned field notes. The field notes have some entries from the time of excavation, while most of them try to make sense of the provenience system used in the 1970s. Some of the provenience notes are illegible due to the quality of the scan, and no originals could be found. However, the notes provided just enough information to identify approximate locations for the majority of the originally excavated cultural assemblage, accomplishing one of the major goals of the UWAR visit.

In addition to locating the valuable but limited documentation of the original excavation, the next goal of visiting the UWAR facility was to collect cervid (mule deer) teeth for isotopic analysis and obsidian specimens large enough for further sourcing studies. Luckily, a large quantity of both target specimens was located and pulled for the analysis presented in this dissertation.

Chapter 3 – Perspectives of Land Tenure and Territoriality: Theoretical Implications and Hypotheses

Using data from obsidian sourcing and stable isotopes to address social group organization and hunting strategies, one can begin to address hypotheses concerning land tenure and territoriality. Discussions of human territoriality have centered around the notions of land tenure, sharing, exchange, and risk, providing sophisticated ecological models to apply to human foragers (Cashdan 1983; Dyson-Hudson and Smith 1978; Kelly 2013; Smith 1981; Thomas 1981; Winterhalder 1986). More recent studies have evaluated these models against the archaeological record in the southwestern United States (Eerkens 1999; Schriever 2012; Zedeño 1997) and the region in which this study is focused (Reckin 2018; Reckin and Todd 2019). The ecological models assess resource and/or territorial defense strategies by human foragers specifically by focusing on the cost and benefits of territoriality by our culturally complex species.

Theoretical Approaches

Cashdan (1983) argues that there are two distinct "mechanisms" that human foragers use to control access to territorial resources. The first mechanism or strategy is referred to as "perimeter defense", which involves direct competition for territorial space between groups of human foragers. Human foragers employing the perimeter defense strategy define physical territories and control access to space inside, which contains the valuable resource(s) that determine the territory boundary. According to Cashdan, there will be little movement by individuals between small territories with dense and reliable resources. This scenario is displayed in one of the scenarios of Dyson-Hudson and Smith's (1978) economic defensibility model (EDM). This model compares resource density and predictability creating four different spatial scenarios as related to the defense of resources (Dyson-Hudson and Smith 1978: 26). Thomas (1981) applied this model to ethnographies of human foragers in the Great Basin, focusing on the impacts of seasonality. His study concluded that different societies practice more or less territoriality during different seasons. The variable ecological conditions of three different indigenous bands in the Great Basin correlated with a high degree of variation in their economic defense of resources. The Owens Valley Paiute, for example, practiced a high degree of territoriality, given that their resource base was more dense and predictable. The Kawich Mountain Shoshone lacked any form of territoriality and traveled great distances to find food and water, given the sparse and scattered distribution of these resources. The Reese River Shoshone falls in between the previously mentioned groups. Tracts of piñon (*Pinus edulis*) trees and the upland sowed seed areas were clearly defined by landmarks and were defended and even passed down through the matrilineal line (Thomas 1981). The decision to defend these winter piñon villages exhibited the importance of the predictable and very dense resource. However, in stark contrast with the piñon groves, the plant materials on the valley floors, in addition to hunting and fishing grounds, were not defined nor defended by the Reese River people. These ethnographic examples show that land tenure and territoriality strategies play out in unique and variable ways that can be more complicated than the standard models may predict. Empirically, however, the seasonal change in strategy typified by the Reese River Shoshone makes perfect sense given a specific resource's seasonal predictability and value.

The second strategy outlined by Cashdan (1983) is not concerned with the direct control of territorial space (and therefore resources) but instead focuses on control of access to social groups who practice reciprocal altruism. This second strategy can also be referred to as "social boundary defense", the term used in this study. This strategy develops among human foragers when resources are or become sparse and unpredictable, leading to larger ranges. As these ranges become larger, it becomes less economical or impossible to restrict physical access to the territory. As a result, the defense and restrictions shift from physical territory to access to a particular social group. A social group in a particular area or range has unique knowledge of the distribution and density of resources that vary seasonally. An "outsider" would not have this knowledge and would risk a great deal to venture into a territory in which they do not have access to the expertise of a local group. Social boundary defense is also displayed as a scenario in the Dyson-Hudson and Smith (1978) model where they argue that resources are utilized through information sharing, and that spatio-temporal territory may arise if resources become seasonally dense. On the other hand, if a foraging group's knowledge of the area was shared, there would not be a great deal of risk in the new territory for an outsider. It is argued that these relationships between groups are not fixed and can vary in relation to the state of a group's resource base. If groups can assist one another in times of hardship or starvation, the social boundaries will remain open between them, leading to increased sharing of resources. Winterhalder's model of inter-forager food sharing (1986) illustrates this argument at the individual level, while Kelly (2013) modifies the model to translate it into the relation between groups of foragers.

The original Winterhalder (1986) model compares the variance in resource returns to the degree of correlation between the return rates of various individuals, highlighting four different outcomes. Kelly (2013) swaps the individual for a human foraging group to look at the variability of group members' total effort compared to the correlation between the returns of different groups and is more suited for application to the archaeological record. In Kelly's model, social boundary defense occurs when the intragroup variance is high, and the intergroup correlation is low. High variance in group return rate means that the group doesn't always collect the same amount of resources, thought of as food in this model. This situation can lead to an abundance of resources one year and disastrous starvation in another. High variance could potentially lead to a group calling on a nearby group for assistance given the highly variable return rate. A low correlation between groups means that different groups have different resources bases meaning that if one group is struggling, the other could potentially assist, given that they target different resources or a different geographic area.

The models and scenarios discussed above were developed from and applied to ethnographic examples to evaluate human foragers' land tenure, sharing, and exchange strategies. However, these models can also be tested with the archaeological record. Fortunately, studies assessing the variables in these models have been conducted in the GYE, where this study is located. Obsidian sourcing studies have made it possible to track the movement of lithics across the landscape, allowing research to address questions of the utilization and conveyance zones of obsidian, especially in the GYE (Adams and MacDonald 2015; Cannon 1993; Finley et al. 2015; MacDonald et al. 2011; MacDonald 2014; Reckin 2018; Reckin and Todd 2019; Park 2010, 2011; Scheiber and Finley 2011; Whitman 2013). While some of these studies do not specifically test a prediction of the land tenure models, they provide valuable insight into the seasonal rounds of distinct foraging groups. Studies of land use and tenure, sharing, and exchange using obsidian sourcing have led to multiple interpretations and models of human foraging groups in the GYE. These two opposing models can be referred to as the Single-User Model (SUM) and the Multi-User Model (MUM) as referred to by MacDonald (2014), first described by Johnson et al. (2004). The SUM model suggests that the GYE region was utilized by one group of human foragers during their seasonal rounds (Finley et al. 2015; Scheiber and

Finley 2011). Scheiber and Finley (2011) argue that the Central Rocky Mountains, a large portion of the GYE, were part of a "pan-Shoshone" landscape by at least the Late Archaic. Their evidence lies in obsidian source diversity from archaeological sites in the Wyoming Basin to assess patterns of mobility and exchange in the region. They postulate that territory contraction can be seen in the archaeological record by a reduction in obsidian source diversity between the Late Prehistoric Period and Historic period (Scheiber and Finley 2011: 380-385). While the ethnographic evidence shows that the Sheep Eater Shoshone were the primary residents of this region in the historic period (Nabokov and Loendorf 2004), Finley et al. (2015) suggest that overlapping conveyance zones of the Wyoming Basin and Yellowstone Plateau represent tebíwa, or foraging territories (Smoak 2006). They argue that these territories have been in place for much longer, since the Middle Archaic (5000 to 3500 BP), aligning with Holmer's (1994) estimation of Numic arrival to the area. The SUM argues that the Numic entrada into the GYE occurred as early as the Middle Holocene, meaning that a single, stable social group claimed the Central Rocky Mountains as their foraging territory (Holmer 1994).

The other model (MUM) suggests that a wide variety of distinct forager groups from a number of regions utilized the area around Yellowstone Lake (Johnson et al. 2004; Johnson and Reeves 2013; MacDonald 2014; Park 2010; Park 2011) and beyond (Reckin 2018; Reckin and Todd 2019). MacDonald (2014) presents a convincing argument that shows a diverse number of human forager groups seasonally occupying distinct parts of Yellowstone Lake using lithic raw material diversity and obsidian point of origin studies using x-ray fluorescence (XRF). Specifically, MacDonald illustrates distinct forager group occupations on the north, east, southeast, and southwest/west shores of Yellowstone Lake, leading to the conclusion that the GYE and, more specifically, Yellowstone Lake, was a "crossroads of multiple tribal and/or band territories" (MacDonald 2014: 156). Reckin (2018; Reckin and Todd 2019) continues to support the MUM in the GYE using obsidian source data, arguing that there is evidence for the existence of multiple socially bounded groups in the GYE, specifically in the Beartooth and Absaroka mountain ranges. The evidence for this conclusion stems from the overrepresentation of Idaho obsidian sources in the Beartooth Mountains, which are preferred to equidistant or closer sources within the GYE (Reckin and Todd 2019: 447). The Absaroka Mountains were shown to have a different obsidian source signature than the Beartooths and had an underrepresentation of the Bear Gulch obsidian, which was overrepresented in the Beartooths, indicating differential access to the source between the areas (Reckin and Todd 2019). The connection of the Beartooth Mountains to the Snake River Plain fits the social-boundary defense model, given that the resource base between the two areas was significantly different, therefore making it easier to come to one another's aid during times of hardship. Given the lack of evidence of this phenomenon in the Absaroka Mountains, it appears that multiple groups of human foraging social networks were at play, having distinct connections with groups in other geographic areas.

The ethnographic record also supports a MUM of the GYE given the accounts of the seasonal rounds of around half a dozen indigenous groups, including the Shoshone, Crow, Blackfeet, Bannock, Salish, Kiowa, and Nez Perce. Nabokov and Loendorf (2004) paint a detailed account of these indigenous groups operating permanently and seasonally within the GYE. The discussion describes tribes historically traveling from all cardinal directions to utilize the resources found on this important landscape. Nabokov and Loendorf (2004) even describe ethnographic accounts of the Crow utilizing the Sunlight Basin area where 48PA551 is situated, post 1000 BP.

Hypotheses

Given the evidence discussed above, it seems likely that the GYE was inhabited by many distinct human foraging groups who practiced a form of social boundary defense. Each hypothesis below represents a different combination of land tenure and hunting strategies which seeks to shed light on the behavior of hunter-gatherers in the Middle Holocene Rocky Mountains. Specifically, each hypothesis seeks to determine whether one or more social groups were operating out of this winter hunting camp, with the major implication being that this area was potentially a communal hunting ground. The hypotheses also distinguish whether the mule deer recovered at the site was the result of a low number of mass kill events (i.e., game drives) or whether it was from chance encounters on the landscape with a few individuals being accumulated over time.

Hypothesis 1 – Cooperative Hunting and Winter Aggregation of Distinct Social Groups in a Communal Hunting Ground

This scenario postulates that groups from multiple, distinct social networks aggregated during the late fall through the early winter to participate in communal hunting. The faunal assemblage showing a preference for mule deer is the result of a single, catastrophic, or large-scale kill event stemming from a communal, drive-like harvesting strategy. The catastrophic kill scenario has some support in the faunal assemblage recovered in the original excavation (Frison and Walker 1984) as a result of the analysis of population dynamics of mule deer through sex ratios and age distribution (Simpson 1984). Given that this site lies near the boundary of the Absaroka and Beartooth mountain ranges, it falls in between the identified social boundary defense zones outlined in Reckin (2018) and Reckin and Todd (2019). In this scenario, the social boundary defense strategy is relaxed during the winter due to the difficulties of travel and resource procurement in the mountainous environment. This represents an inverse scenario to that of the Reese River Shoshone, who increased the defense of piñon resources during the winter (Thomas 1981). This aggregation and relaxation of social boundary defense led to the consideration of this area as a communal hunting ground.

Hypothesis 1 Expected Supporting Evidence:

The population dynamics of the mule deer should reflect a herd of related individuals given the known sex ratios and age distributions of modern mule deer herds during the late fall to early winter. During mating season (late fall/early winter), male mule deer are fewer in number than does in any given area, and breeding herds will have a male to female (adults) ratio of about 1:4 (Mohler et al. 1951; Simpson 1984). A catastrophic mortality event is reflected by an age profile of a living population made up of a large proportion of juveniles, followed by adults making up the next largest proportion, and a small proportion of older adults (Nimmo 1971; Reher 1970; Reher and Frison 1980; Frison 1980). Thus:

Stable isotopic measures of mule deer tooth enamel bioapatite, including carbon, oxygen, and strontium, should exhibit limited variability in values between individuals, further reflecting the relatedness of individuals. δ13C values should reflect a very similar vegetative diet among individuals. δ18O values should reflect a similar source of dietary and drinking water among individuals. 87SR/86SR values should reflect a similar spatial distribution and migration route of mule deer individuals due to the specific bedrock strontium signature from in ingested plant foods. The three isotopic values together should show limited variability reflecting a similar diet, water source, and spatial distribution on the landscape among a single mule deer herd.

There will be significant diversity in obsidian sources, indicating different social networks between distinct groups of human foragers. There will be spatial segregation of specific obsidian sources across the site, indicating the separation of occupied space by distinct groups (see next test expectation for discussion of residential units). The obsidian sources will show distinct social connections representing obsidian conveyance zones within and potentially outside the GYE.

Hypothesis 2 – Winter Aggregation of Distinct Social Groups in a Neutral Hunting Ground

Under this hypothesis, members from different, distinct social groups aggregate in the same area, either at the same time or during the same season, to participate in big game hunts. However, communal and cooperative hunting through game drives does not occur. Instead, the hunting is completed by smaller groups within the same social network, taking small numbers of mule deer from the late fall to the early winter season. The faunal assemblage is then an aggregation of remains over time from attritional kills. As mentioned in the first hypothesis, the social boundary defense strategy is relaxed during the winter, given the difficult conditions. However, cooperation between groups with distinct social networks does not occur, and groups only hunt for their own group. The aggregation of social groups and the seasonal relaxation of social boundary defense makes the area neutral ground open for hunting.

Hypothesis 2 Expected Supporting Evidence:

The population dynamics of the mule deer will not reflect a herd of related individuals as seen in the sex ratios and age distributions of modern mule deer herds during the late fall to early winter (Mohler et al. 1951; Simpson 1984). Instead, the age profile of the harvested mule deer will reflect an attritional kill profile reflected by larger proportions of young and very old individuals (Reher 1970). The sex ratios will not be consistent with a breeding herd and will have a male to female ratio significantly different ($>1\sigma$) than the expected 1:4 ratio. Thus:

Stable isotopic measures of mule deer tooth enamel bioapatite, including carbon, oxygen, and strontium, should vary significantly in values between individuals, reflecting a different foraging history. δ13C values will reflect a varied vegetative diet among individuals indicating that they were not related and were not foraging in the same areas. 𝛿18O will indicate a variable water source among individuals, showing that they potentially came from different watersheds before death. 87SR/86SR will show different migration routes of individuals, showing that they were not traveling together and were therefore not related to one another. The variability of these isotopic values indicates that small numbers of individuals were hunted and accumulated over a longer time period rather than during a single, catastrophic event.

The diversity of obsidian sources under this hypothesis will be consistent with the previous hypothesis. To recall this expectation, there will be significant diversity in obsidian sources indicating the presence of different social networks between distinct groups of human foragers.

Hypothesis 3- Winter Aggregation of a Single Social Group for Communal Hunting

This hypothesis suggests that the site was occupied by members of a single social group comprised of small bands who come together during the winter. This strategy is described by Shimkin (1947), who notes that the Eastern Shoshone were known to disperse in the summer and aggregate during the winter months. This strategy also falls within the arguments of Finley et al. (2015) and Scheiber and Finley (2011) and the Single-Use Model of the GYE by members of the Mountain Numa, though the presence of other social groups may still very well exist per the discussion above. The hunting strategy represented here is cooperative and communal among related bands participating in a drive-like event resulting in a catastrophic kill, as supported by early interpretations (Simpson 1984). Given the presence of other potential social groups in the area (Reckin and Todd 2019), this scenario suggests that social boundary defense (and potentially perimeter defense) is the strategy utilized by the sites' occupants. Wildlife biologists agree that mule deer are one of the most predictable ungulates in the GYE (Bishop personal communication; Hayden et al. 2008) in reference to their consistent seasonal rounds, diet, social behavior, and migration. The high predictability of the resource and the presence of only a single social group at the site potentially provides evidence that the seasonal land tenure strategy of perimeter defense is being exploited, much like that of the Reese River Shoshone and piñon groves (Thomas 1981).

Hypothesis 3 Expected Supporting Evidence:

The population dynamics of the mule deer should reflect a herd of related individuals given the known sex ratios and age distributions of modern mule deer herds during the late fall to early winter. During mating season (late fall/early winter), male mule deer are fewer in number than does in any given area and breeding herds will have a male to female ratio of about 1:4 (Mohler et al. 1951; Simpson 1984). A catastrophic mortality event is reflected by an age profile of a living population made up of a large proportion of juveniles, followed by adults making up the next largest proportion, and a small proportion of older adults (Nimmo 1971; Reher 1970; Reher and Frison 1980; Frison 1980). Thus:

This expectation also remains consistent with hypothesis one. Stable isotopic measures of mule deer tooth enamel bioapatite, including carbon, oxygen, and strontium, should exhibit limited variability in values between individuals, further reflecting the relatedness of individuals. 𝛿13C values should reflect a very similar vegetative diet among individuals. 𝛿18O values should reflect a similar source of dietary and drinking water among individuals. 87SR/86SR values should reflect a similar spatial distribution and migration route of mule deer individuals due to the specific bedrock strontium signature from in ingested plant foods. The three isotopic values together should show limited variability reflecting a similar diet, water source, and spatial distribution on the landscape among a single mule deer herd.

In this scenario, the sources of obsidian will not be highly variable and should reflect a single social network or conveyance zone. There will be no spatial segregation of obsidian sources across the site because only a few obsidian sources will be present. The limited variability in obsidian will indicate a small number of point(s) of origin source(s) indicating the social tie(s) of the site occupants.

Conclusion

The following chapters dive into the analytical sections of this dissertation and begin to test and assess the hypotheses and expectations discussed above. Chapter 4 provides important context and demonstrates the essential role of collections research and geophysics, it will not necessarily contribute to the hypotheses discussed above. However, Chapters 5 and 6 will provide the crucial analysis and data which can be used to test each of the three hypotheses discussed above. Chapter 5 will focus on the obsidian sourcing analysis and draw conclusions about obsidian conveyence and social groups in the GYE. Next, Chapter 6 will center on the results of the stable isotope analysis which seeks to address the mortality events of the mule deer at the site. Chapter 7 will use the previous chapters' findings to discuss the more robust hypotheses and test expectations discussed above. Using both the results from the obsidian and isotope analyses, we can draw final conclusions about the land tenure and territoriality strategies at 48PA551 and discuss the implications for our understanding of complex hunter-gatherers in the Middle Holocene Rocky Mountains.

Chapter 4 – Collections Research and Remote Sensing at 48PA551

The main portion of 48PA551 was excavated in the late 1960s and early 1970s when excavation techniques, record keeping, and map-making were less detailed and before specific standard operating procedures were in place. This situation is not unique to this site, and likely applies to sites across the west. While the significant findings from the early investigations are well understood (Frison and Walker 1984), many questions remain. Most importantly, the horizontal and vertical spatial context of the large, previously excavated assemblage is not well understood. What remains of this context must be pieced together through incomplete records, poor quality copies of field notes, verbal recollections of events over 50 years old, and a primarily uncatalogued collection of artifacts that has sat untouched in a curation facility since the 1980s. However, the backfilled and reburied excavation units and yet-to-be unearthed archaeological deposits remain beneath the surface.

In 2017, the University of Montana began fresh archaeological investigations at the site, starting with the first phase of geophysical survey utilizing magnetic gradiometry. Dr. Steven Sheriff, Professor Emeritus at the University of Montana Geosciences Department, conducted total field magnetics data collection to identify subsurface, thermoremanent features, and any other cultural or geological features worthy of subsurface testing. Following the magnetic survey results, this author conducted ground-penetrating radar (GPR) during the summer of 2018 to further resolve subsurface features and ground-truth results. After test excavation of geophysical targets, a visit in early 2020 to the University of Wyoming Archaeological Repository (UWAR) was made to obtain further records, samples, and additional documentation of the original excavation. This collections research was completed to support the findings of the 2018 excavations and to lay the groundwork for future research.

This chapter will demonstrate how the combination of geophysical survey and collections research can revive old datasets and set the stage for fresh archaeological investigations at sites that deserve a second look. The ultimate goal is to provide a blueprint for similar investigations and a standard operating procedure for minimally invasive archaeological testing and subsurface evaluation. The first step discussed in this chapter is collections research and the crucial information required for a successful subsurface investigation. Curation facilities such as the University of Wyoming Archaeological Repository (UWAR) have incredible datasets, likely filled with clues and assemblages containing significant future discoveries; however, the scope of these collections, even at individual sites, is often overwhelming. The first part of this chapter suggests the critical first steps to approach an undertaking like that conducted at 48PA551. This section will also include a brief overview of the state of the collection at this site, including what is available, how it is organized, and what is still missing.

Following the discussion of collections research, the focus will shift to the application of remote sensing, specifically geophysical survey, to site 48PA551. While geophysical surveys successfully identify cultural features in areas with previously unknown archaeological deposits, they excel in areas with known deposits. 48PA551 offered a rare chance to apply ground-penetrating radar (GPR) and magnetic gradiometry to a site known to contain many prehistoric thermal and pit features. In addition, the site was excavated in large, block excavations, which provide another target for geophysical equipment. The old block excavations provide the key link between the collections research and modern investigations. The goal is to evaluate how successful geophysical prospection can be in providing the subsurface geological and cultural context found at 48PA551. In addition, I seek to determine if excavation units are visible in geophysical data and if disturbed excavation areas can be resolved distinctly from intact, prehistoric features.

This chapter addresses outstanding questions at 48PA551 stemming from the collections research and the geophysical survey. First of all, are the records associated with the original 48PA551 excavations detailed enough to contextualize the original findings? In other words, do the provenience data, maps, and other records give exact enough locations of the cultural assemblage to "re-create" the excavation? If so, it could set the stage for more robust research that encompasses the entire original dataset and allow for new interpretations and analyses. Secondly, between the records and the geophysical results, can the *exact* locations of the old excavation units be located? The exact locations would assist with the physical context of the original findings and locate areas to avoid during new excavations. Finally, can ground-penetrating radar and magnetometry locate unexcavated areas and undisturbed deposits containing archaeological material? While this question may seem simple, many factors can affect the outcome of a geophysical survey, including depth of features, the contrast of features, subsurface and surface conditions, and other issues discussed in the following sections. If successful, this scientific approach may substantially impact future archaeological investigations and illustrate the important intersection of collections research and geophysical survey.

Geophysics Background

Geophysical assay in archaeology has a long tradition (for reviews, see Clark 2001; Conyers and Goodman 1997), but until recently, its popularity remained largely with European audiences. In his seminal article, Kvamme (2003) raises the American archaeological community's attention to the power and potential for geophysical application to the archaeological record. The use of geophysical applications in North American archaeology has steadily been on the rise, and today, we are beginning to see its application beyond academic research and in cultural resource management contexts.

Geophysical prospection provides two benefits to the archaeological community in the form of efficiency and non-destructive survey. Geophysical surveys have the potential to complete detailed subsurface mapping over a large expanse. These surveys are often quite detailed and can provide non-destructive imagery of subsurface archaeological deposits unachievable through traditional archaeological methods. These qualities of geophysical survey, namely efficient survey and detailed non-destructive subsurface description, provide an intuitive utility of archaeo-geophysics for cultural resource management.

Geophysics in archaeological investigations is often associated with major data recovery efforts at archaeological sites with intensive cultural occupation. These efforts include historic sites with identifiable structures and features, prehistoric village sites or sites with identifiable structures/architecture, or deeply stratified prehistoric sites. Geophysics within this context allows for a better evaluation (especially for NRHP eligibility) of archaeological sites with limited surface expressions. This type of use also sets up surgical subsurface testing of features to obtain datable material and assess cultural deposits' extent. Geophysical investigations, while extremely helpful, are not always appropriate or even possible in some contexts. Various factors, including surface and subsurface conditions, may affect or preclude the completion of a geophysical survey. Ernenwein and Hargrave (2009) identified six distinct questions that need to be addressed before fieldwork. The questions are as follows:

1. Are archaeological features likely to be present at the site?
2. Do the archaeological features have enough contrast with the surrounding matrix?
3. Are the archaeological features large and shallow enough to be detected?

4. Will the archaeological features stand out from surface and subsurface clutter?
5. Is the ground suitable for the passage of geophysical equipment?
6. Is the near-surface suitable for geophysical investigation?

The first question is a fairly obvious question to evaluate and can usually be answered based on the surface expression of the archaeological site. However, sometimes it may not be as obvious if archaeological features are from surface artifacts or features. In this case, depositional environments can provide the contextual clues needed to decide whether or not a site even has the possibility for subsurface features.

Contrast with surrounding subsurface soil matrix is also a factor in geophysical prospection for identifying cultural features and material. For successful geophysical data collection, archaeological deposits must contain contrasting magnetic, resistive, or reflective properties (depending on the geophysical technique) to appear unique in a substrate. The properties of the soil matrix and the cultural features also need to have characteristics that are susceptible to these measurement techniques. The soil type, moisture content, clast size, bedrock depth, water table depth, and other subsurface characteristics influence how geophysical signals behave and how measurements are recorded.

Another factor to consider is the size and depth of the expected archaeological features. Ernenwein and Hargrave (2009) suggest that objects smaller than 25 to 30 cm will not readily be detected by any method (besides strongly magnetic objects made of ferromagnetic material). The array of available instruments has a range of maximum prospection depths ranging from a few centimeters up to at least seven meters below the surface (or below the sensor). A general sense of the depth and nature of the targeted archaeological features will influence what equipment is used for detection.

Surface and subsurface clutter will affect the quality of data and data collection itself. A cluttered surface with large artifacts or features (especially at historic sites) can create a frustrating surface for data collection. If surface clutter is serious enough, then the geophysical signals can be interrupted or even record artificial data (especially from metal artifacts). Subsurface clutter includes data created by things such as tree roots, complex strata, reflective soils, and more. This type of "data" clutter will make it extremely difficult to parse through archaeological versus non-archaeological reflections.

Similar to surface clutter, the ground surface conditions are one of the most important factors to consider when planning a geophysical survey. Surface topography and vegetation are perhaps two of the most crucial aspects of understanding a potential project area. Thick surface vegetation and uneven terrain can make data collection nearly impossible due to the inability to walk through or push/pull an instrument, resulting in uncollected or unusable data.

Surface topography such as plow furrows, looter holes, or other types of irregular interruptions also makes data collection more difficult, especially when using an instrument such as ground-penetrating radar where the antenna requires consistent coupling with the surface. Mechanical disturbance from vehicles (such as tire ruts) and traffic from livestock (well-worn cattle trails) create surface irregularities that may preclude accurate data collection.

Ground-penetrating radar (GPR) is an active, non-invasive geophysical method that records the contrasts of subsurface materials (Conyers 2004; Conyers 2006; Daniels 2004; Bristow and Jol 2003; Heimmer and De Vore 1995). The antenna of the GPR emits electromagnetic energy into the subsurface, which is either reflected or absorbed by the contrasts based on the dielectric properties. The resulting reflections are recorded by the receiver in the GPR antenna in a vertical profile. Reflections are generated mostly at the interface between materials with differing dielectric permittivity, such as the boundaries between differing stratigraphic layers where changes in radar signal velocity occur. A two-dimensional radar profile represents the vertical and horizontal stratigraphy consisting of individual traces resulting from a single pulse of energy and the resulting reflections at a given location. These are then stitched together to produce an image of dielectric contrasts. GPR is an established prospection method of historical, archaeological features, including wells, privies, and other shaft features and buried building foundations, trenches, and cultural stratigraphy. This method can identify these features due to the dielectric contrasts between feature fill and surrounding sediment, visible truncation of internal stratigraphic layers, or high amplitude intense signal reflections from bricks or stones.

The depth in which the radar signal can penetrate is dependent on several variables, including antenna frequency, sediment types, moisture content, compaction, and salt content. Higher frequency antennas can identify and resolve smaller targets and sedimentary interfaces, though greater depth penetration is sacrificed. Conversely, lower frequency antennas are capable of greater depth penetration. However, the resolution of the resulting radar data makes the identification of small targets and interfaces difficult. Moisture content may increase sediment density by filling interstitial pore spaces, while soil compaction causes a similar effect by compressing between particles. The presence and amount of water, salt, and clay particles can increase signal conductivity, which translates to a reduction in radar data quality (Conyers 2006: 145). Clays, shale, and other high conductivity materials may also attenuate or absorb GPR signals (Conyers 2004, 2006). The complexity and variability found within some internal stratigraphy of larger strata can make remote sensing with this technique difficult, especially with small archaeological features and unpredictable subsurface conditions.

Magnetic gradiometer surveys are designed based on the properties of geomagnetism. The earth contains three sources of magnetism, its core, crust, and the ionosphere. The sources of magnetism make up the geomagnetic field. Instruments have been designed to make use of the magnetic force and sensor affected by the earth's magnetic field. Magnetometry passively measures magnetic fields in nanoteslas (nT) and measures two types of magnetism. First, magnetometers measure induced magnetism, represented by the earth's omnipresent magnetic field around the instrument, which is strengthened or reduced by nearby magnetic fields (Clark 1996; Ernenwien and Hargrave 2009). Secondly, magnetometers measure thermoremanent magnetic features related to iron, iron oxide, igneous rocks, ceramics, bricks, and fired soils. Thermoremanence is a permanent magnetic field created by the heating or firing of a material and is independently magnetic from external magnetic fields, such as that of the earth (Clark 1996). These created magnetic fields are extraordinarily useful to archaeologists because human modification of the environment commonly creates thermoremanent features from things like fire pits, burned agricultural fields, and burned houses.

However, thermoremanence can occur naturally when lava or magma cools to form igneous rocks or in areas where lightning strikes reach the surface. A magnetometer can potentially pick up artifacts such as pottery, bricks, fire-cracked rock, and other fired artifacts, not necessarily individually (but sometimes) but in concentrations or dense clusters. Topsoil is magnetically rich compared to the subsoil (Ernenwein and Hargrave 2009), so the removal of significant amounts of soil can also be detected by magnetometry. This situation is the inverse of fired artifacts and burned features. Graves may appear as voids or pits, but may also contain subtle magnetic signatures resulting from metal grave goods or remnant metal hardware from historic caskets. Typical magnetic anomalies associated with archaeological features would be several to almost 50 nanoteslas, depending on the targets of interest. Prehistoric hearths, stone rings, and the foundations of historic structures, buried foundation walls, or soil changes at the perimeter of corrals would be at the low end of that scale.

Collections Research at UWAR

In February 2020, I visited the UWAR facility in Laramie, Wyoming, with multiple goals. First, I sought to gather obsidian samples for a robust sourcing study (the focus of Chapter 5) and mule deer molars for a stable isotope study (the focus of Chapter 6). In addition, I sought out all records associated with the collection, including photographs, maps, notes, etc., to better contextualize the samples I collected and to better understand the original excavation. My initial impression of the collection is that little, if anything, has been done with it since the final write-up published in Frison and Walker (1984). Only a portion of the collection has been thoroughly analyzed, including projectile points and larger faunal remains. However, this analysis was mostly conducted by students as part of a class project in the 1980s and has yet to have a second look by professional archaeologists. An old floppy disk from the collection was digitized and contained the database for the faunal analysis. The coding sheets associated with the database were also located, which creates the possibility for a new analysis that wouldn't require handling the entire assemblage a second time.

Much of the collection is spread across the facility in various levels of organization. Projectile points were separated between the formal facility and faculty offices, faunal remains were bagged with partial provenience written on them in permanent marker, mule deer and elk antlers were located in a cardboard box without a lid and any information, and many of the stone tools were not found. It is no surprise that the collection is in this state, given the lack of funding and staffing for facilities such as UWAR, who are given impossible tasks with endless collections. The state of the collection is also a reflection of research trends, as the Middle Archaic is not as popular of a topic in the region as it once was.

Fortunately, there were a handful of original photographs, sketch maps, and field notes to add to the information provided in the limited publications concerning 48PA551. Original photos and field notes provide a much better understanding of where precisely the excavations occurred and what the provenience information in Frison and Walker (1984) refers to. However, there are still some significant gaps in the knowledge of the project background. For example, given that the excavation was conducted by the local Wyoming Archaeological Society (WAS) chapter, most of the crew did not have formal training. Notes indicate that the locations of recovered artifacts were not recorded during the first year of the excavations and that excavation tactics were less than ideal, as indicated by field notes from an unknown crew member. The following is an excerpt from the notes dated 17 August 1969:

> Excavation was continued from yesterday in continuation of same areas. A mano and metate were found by Bob Bales at the backside of Grid 2-A in plot III. Before it was identified as a metate, Mr. Bales put the edge of his shovel under the "rock" to pull it out, and it was broken. It was then excavated into grid 2-B. The mano and metate were both recovered. The metate was found eleven inches deep and about 1/3 in grid 2-A and 2/3 in grid 2-B. It was 18" long and 9" wide. Today we have had a considerable discussion concerning digging procedures. Jim Bales found a mother-of-pearly pendant in situ while doing trowel work and broke it in the process, so people speculated the pros and cons of shovel versus trowel. Nothing definite was decided.

Another section from the field notes from 16 August 1969 discusses how they kept track of where artifacts were found, which paints a bleak picture for the hopes of better understanding provenience. The notes discuss the following situation with Milford Hanson, the director of the WAS crew:

> Milford was given a number of artifacts which had been removed from the excavation Plot 3, Grid 1-A, during the week by Bob and Mary Burns. They kept no records as to where the artifacts were located except for identifying the grid. We tried to ascertain exactly the compass heading on which the excavation is set, but had such a variety of headings on the compasses used that the effort was abandoned until a more accurate device was procured.

These revelations indicate that understanding the exact locations of excavation units based on the maps is quite difficult. Fortunately, the UWAR facility provided photocopies of handwritten notes explaining the plot and grid system. While some of the photocopies are too poor in quality to read, others are legible and at least indicate that some system was in place to keep track of the 5 x 5-foot excavation units (referred to as grids in notes). Horizontal and vertical provenience is less understood and likely doesn't exist for much of the excavated assemblage, as indicated from the excerpts above. Maps included in initial reporting of the excavations and in the 1984 report show the locations of excavation blocks, but neither map is entirely to scale (Figure 4.1).

Additionally, the existing site datum, which was supposedly used for these excavations, is not clearly visible on the 1984 map and is wholly excluded from the earlier map. Like the records, these maps provide general locational information regarding the units but cannot be used to identify the exact locations. A photocopy of a handwritten sketch map provides a sketch of the units with a label indicating that one of the plots occurs 100 feet due south of the datum point. Given that the datum is a known location, marked by a sunken metal bucket, we can plot the approximate location of Plots IV and V from the original excavations based on the maps available (see Figure 4.1). We can then use these known plots and distances to place the main of the original excavation areas in their approximate locations as seen in Figure 4.3.

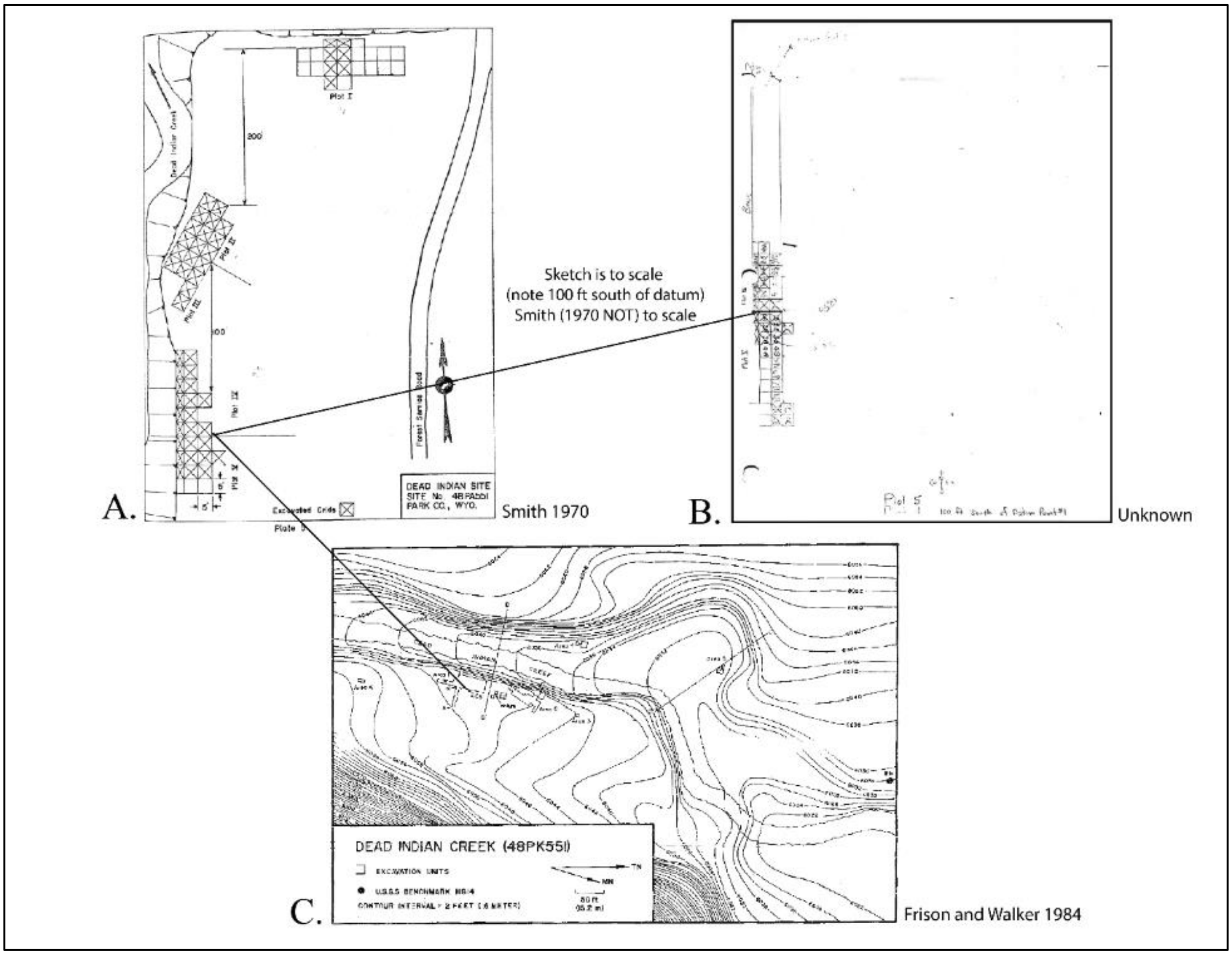


Figure 4.1. Maps from previous investigations matched with excavation sketch map of named units.

There were fewer photos than I had hoped for in the collection, but that doesn't mean that others don't exist elsewhere (Figure 4.2 for examples). The photos present in the collection were split between in-situ features and artifacts following analysis. Hearth and pit features, the rocky area containing mule deer skull caps, and the housepit were all included in the photo collection. The backgrounds of these photos do not provide much context, except for the images of the skull caps and antlers. The background is clearly visible, meaning that the location of this feature can be approximately located in Plot IV or V from Figure 4.2a. Unfortunately, the photo of the housepit profile contains no background context, and its exact location is still unknown. No maps or notes identify the location given that the initial interpretation of the feature was a stream channel, and it was not recognized as a housepit until much later. Artifact photos mostly showed formal chipped stone tools like projectiles, knives, and scrapers, in addition to faunal remains with butcher marks. Some of these photos contain fascinating artifacts, such as the incised or decorated stone in Figure 4.2a which does not receive much attention in the limited literature.

Overall, the collections research results were helpful and addressed many outstanding questions regarding the original investigations. However, the process raised just as many questions as were answered. The exact locations of the original excavation blocks are still unknown, but the records provided clarity on the system (or lack thereof) used to name units. The revelation in field notes regarding the lack of formal record-keeping and less than ideal excavation methods at least manages the expectations of recreating the exact excavation. In general, the collections research process provides a snapshot of the state of the cultural assemblage at UWAR, and this information can hopefully help future researchers interested in 48PA551.

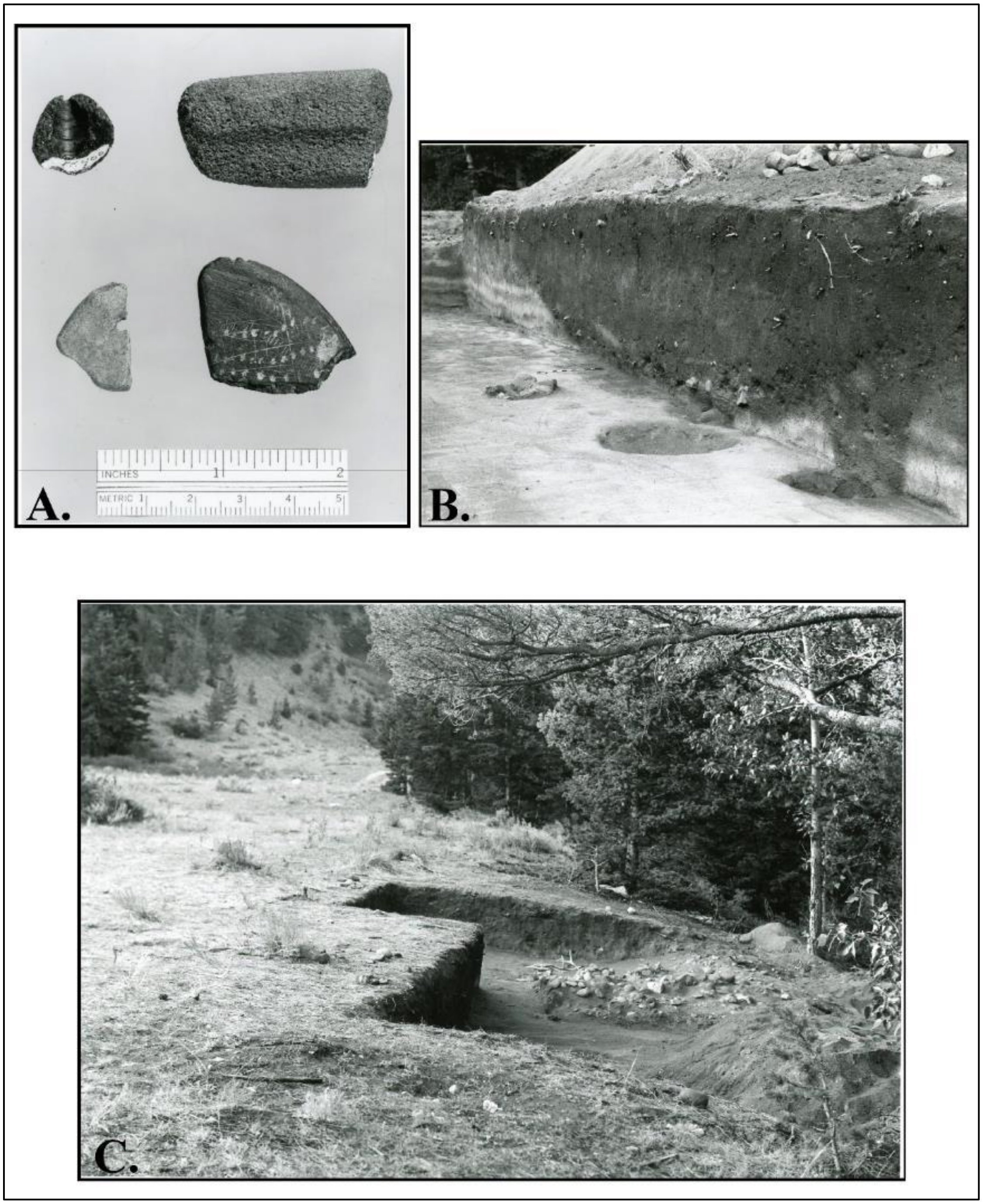


Figure 4.2. Photos courtesy of the University of Wyoming Archaeological Repository; A – Unique groundstone artifacts. B – Original housepit profile. C – Mule deer skull cap feature with visible background.

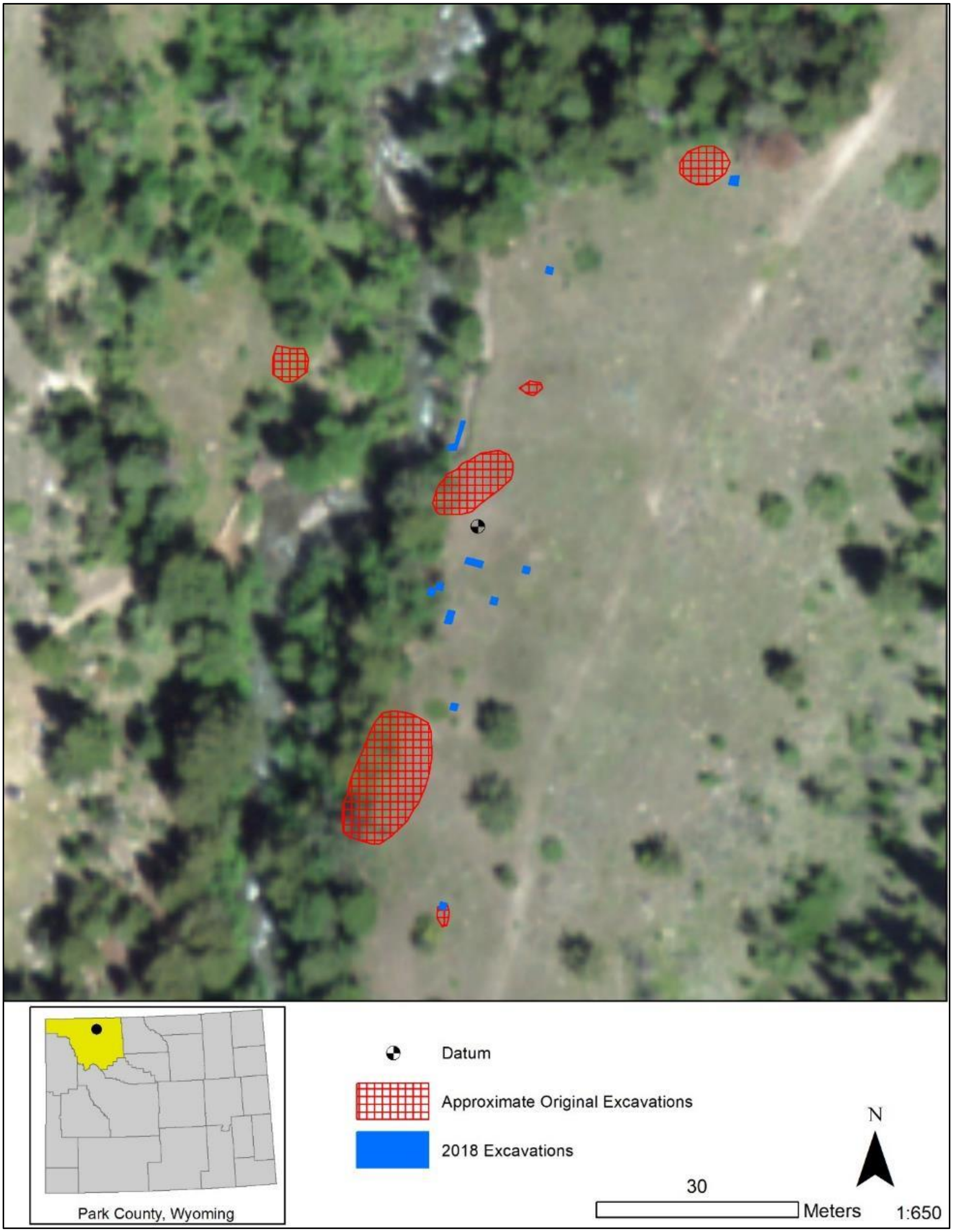


Figure 4.3. Locations of original excavation units and 2018 excavation units.

Geophysics Methods

In the field season of 2017, a reference grid was established with the use of a total station. The grid was created in 10 x 10-meter squares except for the grids located closer to the cut-bank, which were 5 x 10-meters. The datum used for the reference grid was the original datum used in the earlier excavations in the late 1960s/early 1970s (Frison and Walker 1984). This reference grid was the basis for measurements for both geophysical survey and test excavation. Radar data was acquired in seven grids measuring 10 x 15-meters, all within the established total station grid. The equipment used included a GSSI SIR 4000 control unit, a 400 Mhz antennae, and the survey wheel attachment with a distance encoder. Radar data was acquired in transects spaced 25cm apart for high-resolution data, so smaller features were not be missed. These transects were recorded uni-directionally from south to north, starting in the SW corner in every grid except for the first grid, which was initiated from the NW corner with transects oriented from north to south due to active excavation. Data was acquired by distance instead of time, with 50 scans recorded per meter and 512 samples per scan. Before each grid of data was collected, the distance encoder was calibrated to ensure the locational accuracy of the data. Larger sagebrush that would impede the radar survey was removed to ensure that the antennae experienced minimal attenuation.

Acquired GPR data was then processed in the RADAN 7 software program by GSSI using the following techniques, though the processing steps were not necessarily all completed or completed in the same order depending on the grid. Raw data was also reviewed and partially processed in GPR Viewer by Dr. Lawrence Conyers. There is no standard processing approach to radar data, as each technique responds to the uniqueness of each dataset. Each grid was processed separately to best address the challenges they presented. However, the following discussion outlines some of the operations used while processing each grid. One of the first steps is to correct the time-zero in the radar data. This step corrects the true ground surface by removing the "direct wave" from the data. The direct wave is a phenomenon in the data resulting from a portion of the radar wave that is directly passed between the transmitter and receiver within the antenna. This wave appears as a long, continual band of data that is uninterrupted. The base of this wave usually represents the actual surface of the ground where the radar wave first reaches beyond the antenna, making it easy to correct for "time zero" or where the real data starts. A filter that eliminates "vertical" noise or static from the data was used for much of the data in order to make range gain adjustments easier, as data seemed to be greatly affected by competing vertical frequencies. This filter is called an "Infinite Impulse Response" filter (IIR) which employs a bounding "box" to limit the effects of distant scans. The 400 Mhz antennae record frequencies between 100 and 800 MHz, leading to noise from other radio waves (i.e., cellphones, communication towers, etc.). This filter determines the frequencies you want to keep in your data versus those you want to remove. This process is unique for each set of data because if one becomes too aggressive with their filters, then actual data can be filtered out. One of the most critical steps in GPR data analysis is optimizing the range gain levels for the reflections of interest. This step adjusts the brightness and strength of the data, making data and noise much clearer to see. The gain was adjusted by using 10 control points and the exponential adjustment method to manipulate the signal at different depths. Data found deeper in the sub-surface was less clear than the shallower data, given attenuation of the radar signal. The gain was diminished for the deeper data to bring out the reflections from shallower depths that are known to contain cultural deposits (0-100cm). The final step in the general process was to migrate the data. Migration is a process that corrects the data to the real-world depth below the surface and prepares the data for 3D viewing.

This is the general workflow for radar data processing, though additional filters, range gain optimizations, and migrations are sometimes needed to solve unique data characteristics. The interpretation of radar data is a two-step process. The first was to analyze the two-dimensional profiles in their entirety and identify reflections consistent with archaeological features. These signatures include small and/or large stratigraphic breaks, hyperbolic reflections suggesting point-source objects larger than rock cobbles, areas of attenuation (where the signal is absorbed and obscured), and horizontal, planar reflections. The second step was to analyze the three-dimensional time slices to search for discrete geometrical shapes and patterning.

Total field magnetic intensity (TMI) observations were acquired at 10 Hz over the bulk of the site utilizing a Geometrics G858 Cesium Vapor magnetometer within the established reference grid. The sensor was held roughly 40 cm off the ground while collecting data in bidirectional transects spaced one meter apart. In standard practice, transects were guided by a combination of tape measures and target pylons at the end of each grid. A GEM Systems recording Proton Precession base station magnetometer was used for measuring and removing small daily changes in the naturally occurring geomagnetic field. These diurnal corrections were necessary to merge contiguous grids into a single map and to remove the noise with techniques typical for aeromagnetic and ground magnetic data acquisition.

The magnetic observations included features at three dominant scales, which were usually grided by kriging with 0.4-meter spacing. The first of the scales is experimental noise that mostly originates from data acquisition and effects from historic, ferrous metal debris and modern cultural activity. This noise is typically referred to as corrugation or herringbone. Surface and other environmental conditions combine to interfere with the magnetometer operator and impact the distance from the sensor to the ground, in addition to causing variation in walking speed. This appears in TMI observations at 10 Hz as linear magnetic anomalies oriented in the direction of acquisition. This noise is removed from data by a common practice called decorrugation filtering (Urquhart 1988), elaborated on in Sheriff et al. (2010).

The second and third scales of magnetic anomalies in this study are the result of deeper geologic sources and shallow, potentially archaeological sources. The two potential source origins are compared by upward continuation (Jacobsen 1987), a mathematical calculation yielding the magnetic field as if it had been collected at a higher elevation, or matched bandpass filtering. Matched bandpass filtering for anomaly separation has proved to work quite well in archaeological situations, despite its origins in tectonics, structure, and resource exploration (Sheriff 2010). These two techniques separate geological and archaeological sources into equivalent layers to compare their origins. Subtracting the upward-continued results from the TMI observations removes the effects originating from deeper geological sources and isolates magnetic sources within the first two meters of the ground surface.

Geophysical Results

The results from the geophysical investigations are presented in the order they were conducted. Following the geophysical results will be the results of the test excavations that targeted the findings from the magnetometer and GPR surveys. Magnetic data collection is often much quicker than GPR data collection (which requires the antenna coupled to ground), so magnetic data were collected first. GPR data collection then targeted the areas containing the highest probability for archaeological features as indicated by the gradiometry results. Overall, the magnetic range within the first two meters of the subsurface was quite high, reaching nearly 180 nT, well beyond the maximum potential range for the target features (50 nT maximum). However, the data still contain a number of interesting results.

Archaeologically relevant magnetic sources were identified in the shallow subsurface in addition to a smaller number of interesting geologic sources. Strong magnetic highs were concentrated along the western edge of the geophysical grid, corresponding to the highest concentrations of exposed artifacts. Seven distinct sources within this area emerged as slightly stronger centers of magnetism. Given the presence of volcanic rock in this area, these sources (marked with stars in Figure 4.4) did not visually stand out against the background of the overall subsurface magnetic field. However, the magnetic values of these sources indicated a distinct, concentrated increase in magnetism, suggesting that there was more to the magnetic origin than just natural volcanic rock. The initial interpretation of these features suggested that the signatures may be the result of thermal features or concentrations of thermally altered rock, such as secondary FCR deposits from feature cleanout.

In addition to these point features, a handful of larger areas of magnetic contrast may indicate larger features relevant to archaeological investigations. Immediately north of the site datum, an abrupt decrease in magnetic strength occurs along the western edge of the survey area, marking a sharp contrast with the high magnetic readings concentrated in this area. This area (labeled as B in Figure 4.4) may correspond with the location of one of the original excavation block locations, given the sudden boundary between high and low magnetism. Though not as defined, a similar area is located farther south (980m grid line) marked by B’ in Figure 4.4. A third magnetic feature in the bright areas nearest to the datum is marked by contrast but differs from the potential excavation blocks. This area (circled in Figure 4.5), when shown in closer detail, is a circular area of lower magnetism with several smaller contrasting features inside it, suggesting archaeological origin.

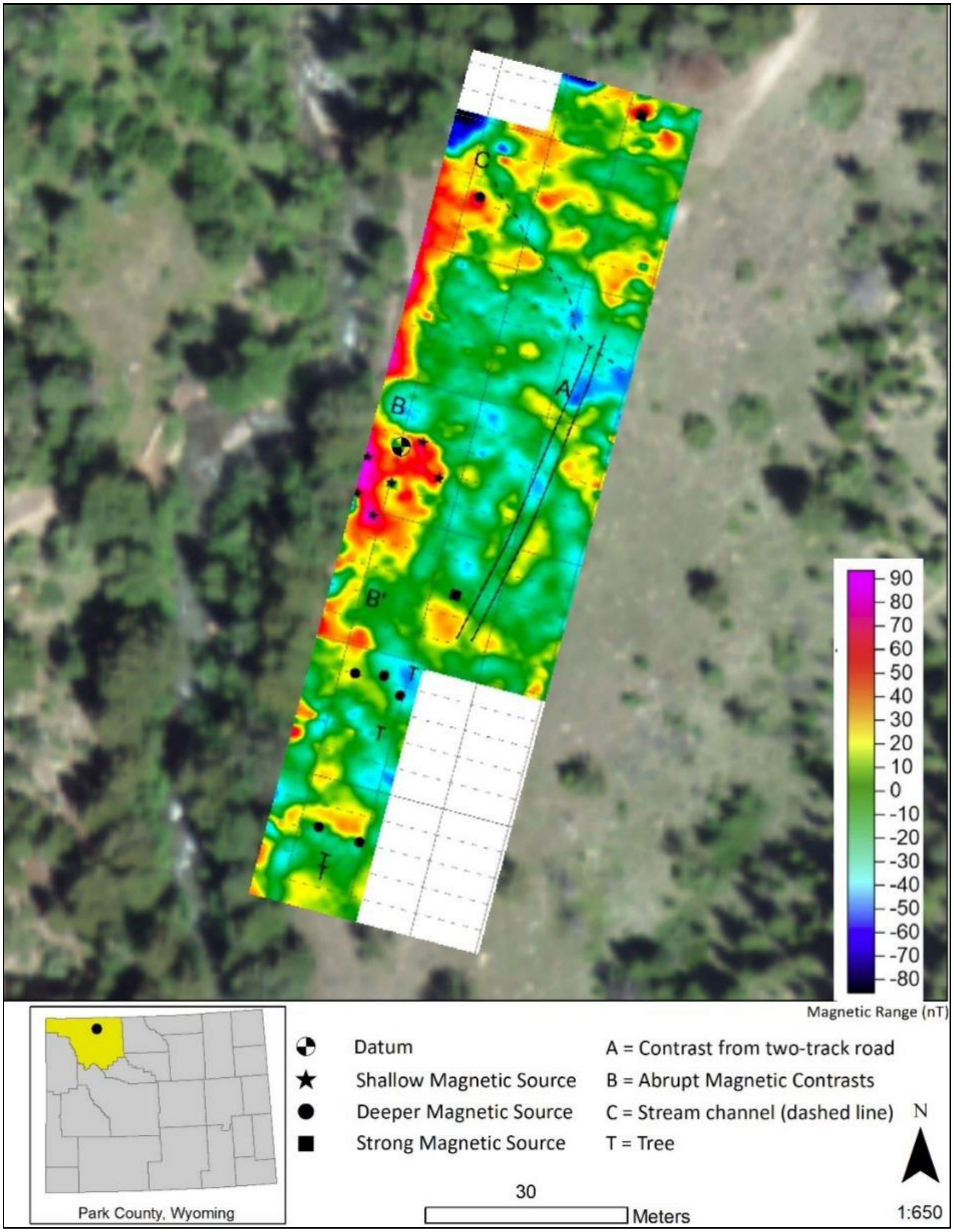


Figure 4.4. Magnetic gradiometer results.

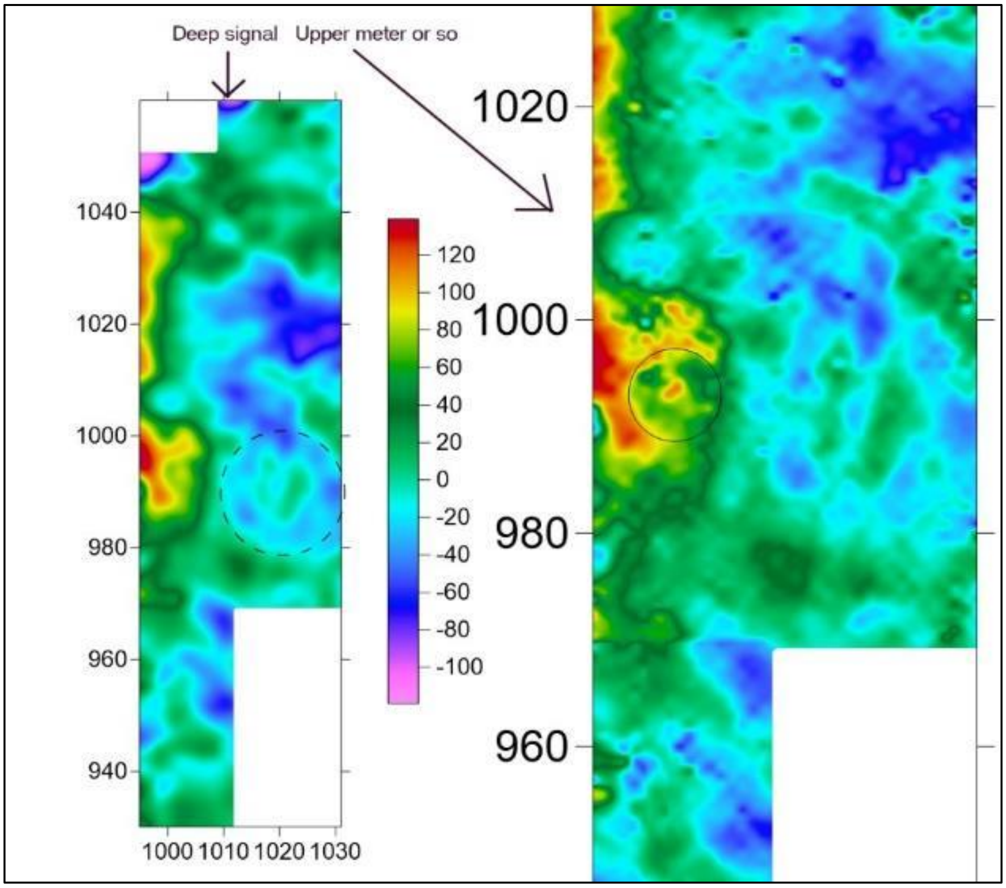


Figure 4.5. Circular area of magnetic contrast.

Five other areas with magnetic sources appear to originate from thermoremanent features slightly deeper than those recognized near the site's western edge. A handful of these are small dipoles, marked on Figure 4.4 with circles, reflecting magnetic characteristics similar to what is expected in hearths or concentrations of thermally altered material. The high-low pairs of magnetic readings are typical of highly magnetized material.

In addition to the potential archaeological features, several larger geological sources are visible in the magnetic field that have cultural significance. For example, punctuated areas of high magnetism beyond the highly magnetic western edge may represent concentrations of volcanic rock, deposited as gravel bars, as evident from the nearby modern stream channel. Specifically, the northern edge of the magnetic survey revealed a linear area of low magnetism trending from the southeast to the northwest. The trough of magnetic lows may represent the trace of an early stream channel that runs towards the current creek. The magnetic lows throughout the rest of the site may very well also indicate a braided pattern of old stream channels.

With the magnetic results in mind, we can better understand the results of the ground-penetrating radar survey. GPR data can better resolve the depth and approximate size of archaeological and geological features in the subsurface. The following discussion outlines many interesting reflections originating from cultural and geological sources. A series of rain events occurred over the four days that radar data was collected. Therefore, signal attenuation due to saturated soil occurs at different depths in the data.

The first grid of GPR data (Grid 1) revealed a circular area of low amplitude reflections surrounded by many high-amplitude reflections in the three-dimensional time slice (Figure 4.6). The high-amplitude reflections originate at a shallow depth within the first 30 cm of the subsurface from point sources, likely rocks or cobbles from older creek deposits. The low amplitude space that forms a circular shape within the cobble reflections results from a refilled incision that removed cobbles and was refilled with much smaller-sized material such as sand. The profile or cross-section of this area confirms these findings (Figure 4.6a), exhibiting an obvious refilled incision into a high-amplitude and more reflective stratigraphic layer. Additionally, the low-amplitude incised area abruptly terminates between 40-50 cm below the surface (14-19 nanoseconds) and is marked by a slightly concave, high-amplitude planar reflection. Some profiles (such as Figure 4.6a) show hyperbolic reflections from point sources within the incised area, indicating the presence of a smaller number of larger clasts or objects. Figure 4.6a illustrates a reflection within the planar reflection marking the base of the feature, indicating a separate, smaller feature. The size, diameter, and cross-section all suggest that this feature has similar characteristics to the housepit previously discovered at the site during the original investigations. It also corresponds to the circular area of magnetic contrast pictured in (Figure 4.5) that discussed earlier, providing two lines of evidence that the area may contain significant cultural deposits. Many of the magnetic areas suggesting thermal features were located in this grid. However, GPR results were inconclusive in identifying these potential features. Corresponding locations were identified in both the profiles and time slices, but the rock-filled soils made further interpretation using GPR very difficult.

Grid 2 was collected 10 meters further north, and slopes down about a meter in elevation. The radar data clearly indicates that the raised area was formed by a cobble-filled gravel bar due to the many high-amplitude point reflections visible in both the time slices and profiles (Figure 4.6b). The high-amplitude areas abruptly end between five and six meters into the grid, corresponding with the abrupt change from high to low magnetism in the gradiometer data. In the western margin of this grid, the abrupt change corresponds with a shallowly buried point reflection found consistently across the first 4.5 meters of the grid. When viewed in the time slices, the reflections appear as a linear and high-amplitude area of reflectivity. A few lower-amplitude hyperbolas originating from point sources are found elsewhere in this grid but do not have a linear orientation or the same brightness. This linear area of reflectivity also corresponds roughly to the southernmost edge of excavation Area 2, visible on original excavation maps (Figure 4.1). While definitive incisions and squared shapes from the original excavation are not entirely visible in radar data in this grid, the abrupt change in reflectivity is suspicious beyond natural soil formation. The profiles in Figure 4.6b and 4.6c identifies a sharp, sloped change in stratigraphy that appears consistent with the slumped wall of a backfilled unit. Backfill settles over time and would likely not maintain a clear, vertical sidewall. Additionally, the magnetic data also exhibits an abrupt change in magnetism, and this area appears "cut out" of the highly magnetic surrounding area. A horizontal, planar reflection (marked by a decrease in amplitude) represents a deeper stratigraphic layer north of the cobble or gravel bar. The sediments above this layer have no intact soil horizons and is relatively unreflective. Given the lack of soil horizons and overall reflectivity from the near-surface and an identifiable horizontal reflective boundary at the maximum approximate depth of original excavations (60 cmbs), the areas identified in Figures 4.6b and 4.6c is consistent with the expected subsurface expression of a previous excavation.

An obvious stream channel in Grid 5 corresponds to the location of a probable stream channel interpreted in the magnetic data (Figure 4.6d). Here, the cobble-filled stratigraphic layer is quite shallow throughout most of the grid. However, the stream channel is marked by a dramatic dip in the layer, which is evident given that the ground surface is flat, with no obvious slope that would affect a layer's distance from the radar antenna. Geological features like this stream channel aid in the decision-making process when selecting test units, given that there is greater soil deposition than surrounding areas with shallow cobble layers. The stream channel was not excavated in 2018 but remains a target for future investigations.

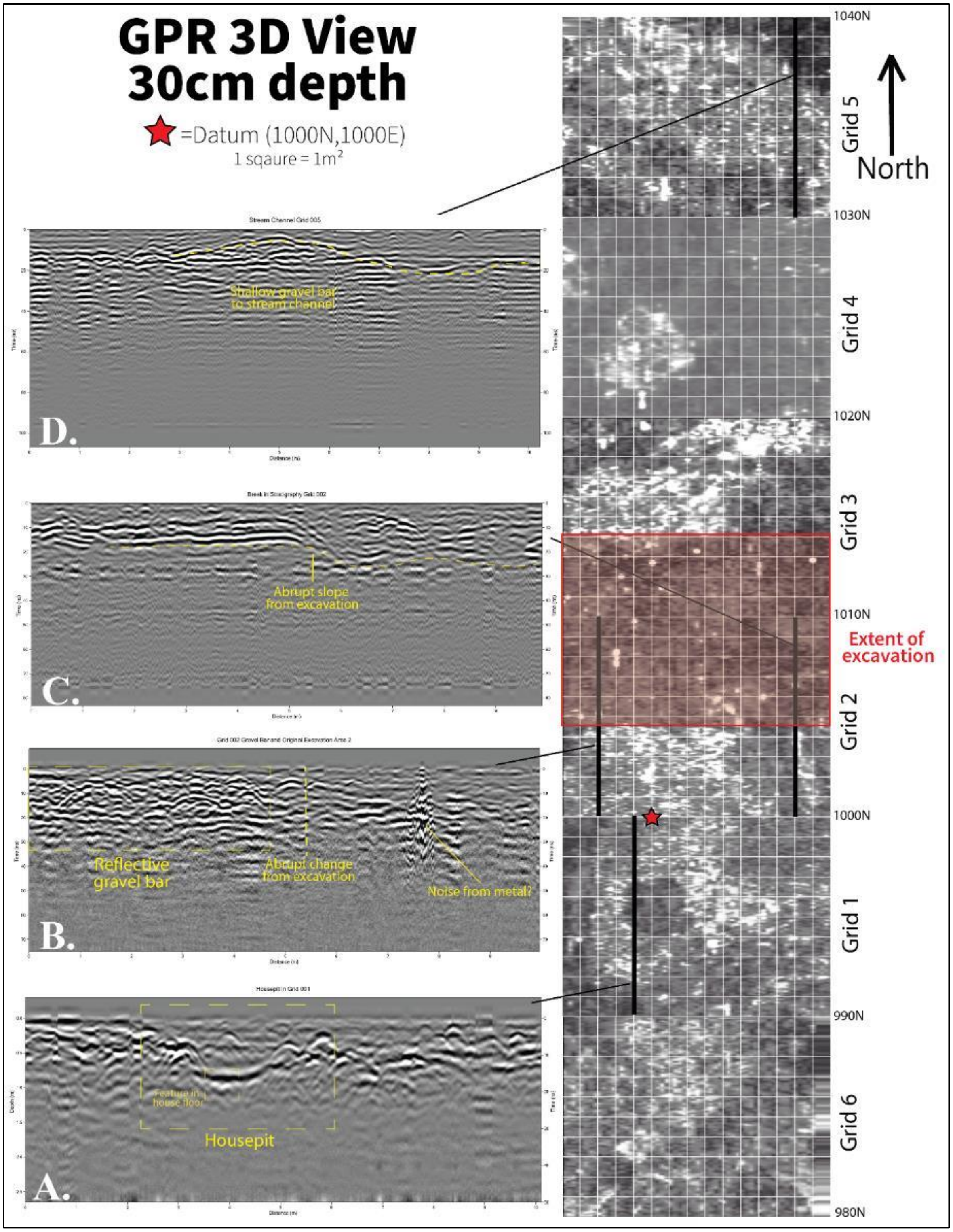


Figure 4.6. GPR time slice at 30cmbs with select profiles.

Single hyperbolic reflections are located throughout the radar dataset, and while interesting and potentially culturally significant, the amount of data collected is too large to address each hyperbola. However, there are clusters of hyperbolas that may indeed represent cultural features. Such clusters appear in most of the grids and are worthy of further investigation. For example, Grid 4 contains a cluster of hyperbolic point reflections across a one-meter area which shallowly buried in an location with known cultural deposits (Figure 4.7). The surface contains no vegetation with roots that would create subsurface reflections, making the area suspicious.

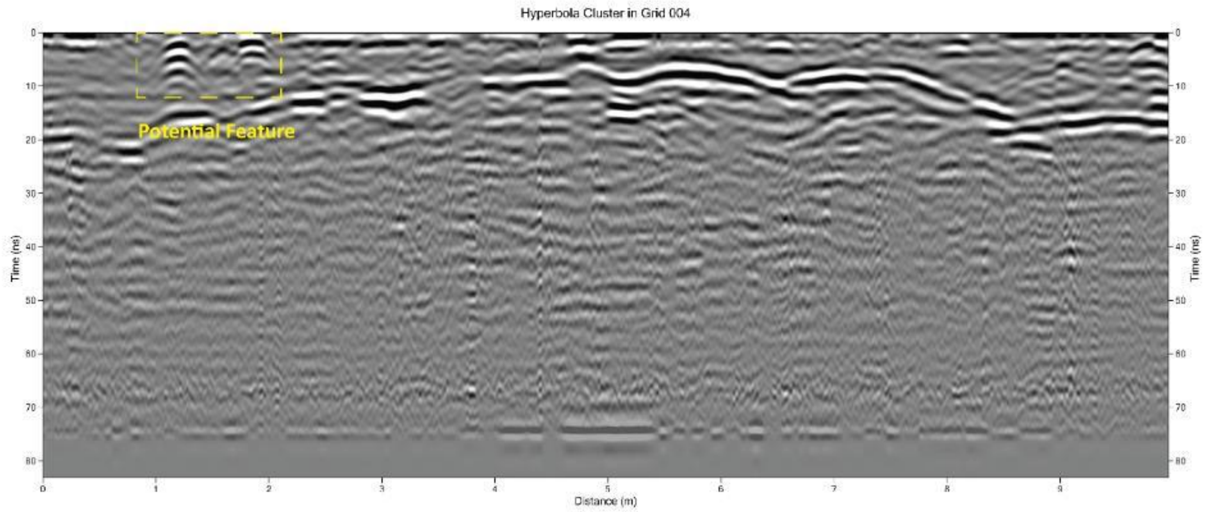


Figure 4.7. Hyperbola cluster in Grid 4.

Test Excavation and Discussion

Test excavation was guided partially by the geophysical results and partially by necessity due to the eroding cutbank exposing cultural material. The results discussed here are limited to the test excavations based on geophysical results. Unfortunately, only one field season of excavation has been accomplished at the time of this writing, so not all of the geophysical results have been excavated. Additionally, most test excavation targeted the magnetic results leaving the radar outcomes mostly untested. In total, 15 potential cultural features were identified with the magnetic gradiometer. Of these, seven were selected for test excavation, and each of the seven potential features revealed thermally altered cultural material that created the magnetic signatures. Three originated from formal thermal features, such as a hearth or roasting pit, which contained a significant amount of charcoal, FCR, bone, and lithic. Two originated from significant FCR concentrations but did not contain formal features, as the magnetism likely came from a secondary or cleanout deposit of the thermally altered rock. At the southern end of the site, an area of magnetic contrast was excavated, resulting in an old test unit from the original excavations. This unit was an outlier in the original investigations, and given the soil contrast between excavated and non-excavated soil, in addition to the potential presence of the original metal corner pins, it created an anomalous magnetic reading. On the original 1984, this is listed as excavation area six.

The circular magnetic anomaly corresponded with the edge of the circular reflective feature located in the radar data. This feature was excavated and revealed a housepit or other basin-shaped footprint of a residential structure (Figure 4.8). The soil profile revealed a black basin shape filled with dark, gritty material and had a compact floor that marked the transition to sterile soil. The black sediment is high in charcoal and other cultural material but only contains a small amount of FCR. The formation processes of this fill require further research but could be the result of decayed organic material that slumped into the depresson or the dumping of debris into the depression when the structure was abandoned. This basin remains the only feature located with GPR that has been excavated. Excavations did not reveal any internal features within the housepit, but only a small portion of the house was excavated. Internal features likely exist given the radar profile data and internal features located in the first housepit that was originally excavated.

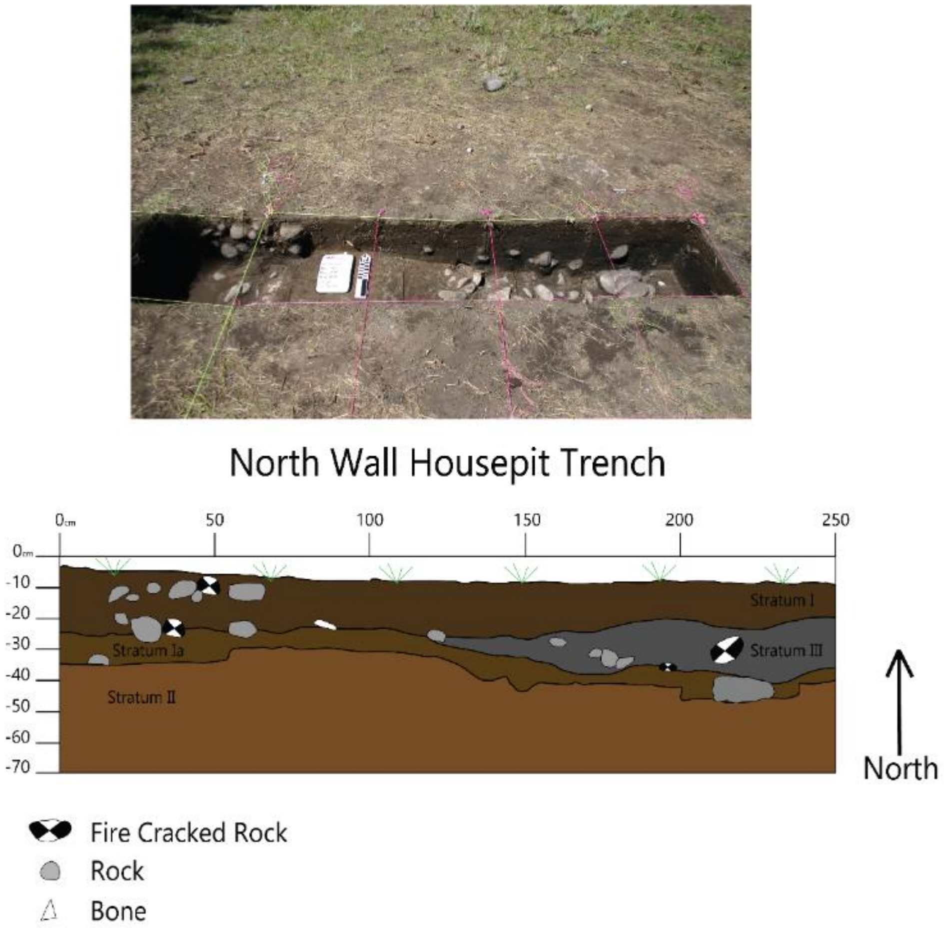


Figure 4.8. Photo and profile of housepit.

Overall, the test excavations based on the geophysical results were successful in identifying important, datable features containing a wealth of cultural material. Beyond these features, the test excavations also revealed important findings regarding the stratigraphy at the site. Most importantly, the test excavations identified a stratigraphic layer marking the bottom of the Middle Archaic occupation, for no cultural material was identified below it. This layer (referred to as Stratum II) is mottled brown consisting of clay-dominated loam that is interspersed among gravel beds. The high points of the gravel beds are likely remnent gravel and cobble bars from the old stream channels. The gravel and cobble deposits also were represented as highly magnetic areas in the gradiometer data, given that the cobbles were mostly volcanic rock. This sterile layer is visible in the radar profiles, as discussed in the previous results. Confirming that cultural occupations reside above this layer allows for a better understanding of the future subsurface potential for archaeological deposits.

Using the depths of Stratum II, where it is identifiable in the radar data, I created a cultural deposition map that shows the likelihood for buried archaeological deposits by depth. This type of data interpretation is extraordinarily important for future investigations at this site and can lead to more informed decisions for further excavations. Figure 4.9 illustrates the approximate depths of potential intact cultural deposits across the site. Much of the area where radar was collected contains soil deposition greater than 50 cm in depth. However, visible gravel bars and Stratum II are closer to the surface in the southernmost and northernmost parts of the geophysical grids. While these areas may contain cultural material, the deposits are not as deeply stratified as other areas.

Figure 4.9. Buried potential map based on GPR data.

Conclusions

At the beginning of this chapter, I identified three major questions to address using the collections research and geophysics results. The first question sought to understand if the original excavation records located at the UWAR facility were intact and detailed enough to use as provenience for the early excavation units and the material they uncovered. In short, the records do indeed provide enough detail to generally place the excavations into spatial context but still leave much to be desired. Field notes and photocopies of provenience information provided some semblance of a unit numbering system that can be partially understood. The field notes provide realistic expectations of what other records may or may not exist, given the lack of formal training amongst the excavation crew. The few maps of the excavations are not to scale and only provide general location information. The orientation and shape of excavation blocks are visible, but it is hard to relate them to exact locations on the ground.

The second and third questions relate to one another and first asked if the geophysical survey could identify the exact locations of the original excavation blocks, while the second question asked if intact archaeological deposits and features could be located. The attempt to locate the original excavation units with magnetics and radar proved to be more difficult than initially expected. However, following the geophysical survey and test excavation, the locations of the blocks have likely been identified, though not to the level of accuracy originally hoped for. Abrupt magnetic contrasts in the gradiometer data and abrupt changes in the radar reflection profiles point to unnatural changes in the subsurface. These contrasts are quite visible in the vicinity of original excavation Area 2, located between 10 and 20 meters north of the datum. Test excavation at the southern end of the site revealed the location of the original excavation Area 6, confirming its exact location. Using this confirmed location makes referencing the original maps much easier, given that they are not entirely to scale. Figure 4.3 plots the locations of the original excavation blocks, along with those from the most recent investigations. Overall, the location of the main blocks from the original excavations have been identified, though the exact boundaries are not readily apparent. A way to confirm the boundaries would be to excavate near the approximate boundary and find the edges, similar to how original excavation Area 6 was located.

The final goal of this chapter was to test how well the geophysical survey could identify intact subsurface cultural deposits and features. The results of the geophysics far exceeded the original expectations. The magnetic data alone identified 15 locations of subsurface thermal features, seven of which were excavated and produced formal features or important concentrations of cultural material. The GPR results identified an extraordinarily important feature, a housepit, a handful of potential pit features, and provided essential profiles identifying varying levels of soil deposition. Figure 4.9 shows the depths of potential cultural deposits based on the relationship between the identifiable stratigraphy in radar profiles and the results of test excavation which identified a sterile clay layer and river cobbles. This provides important subsurface information that can set the stage for future excavations that target areas with the most soil deposition. The GPR also identified clusters of hyperbolic reflections in otherwise unreflective soils, which may indicate the presence of cultural features. While none of these areas have been excavated, they provide target locations for the future.

This approach to subsurface investigations can serve as a blueprint for future archaeological research. An unfathomable amount of cultural material sits in curation facilities waiting to be re-examined, which has sat untouched for decades. Collections research does not have to end in the facility, and the findings can be used to launch new field investigation at sites that have already been partially excavated. Using geophysics to assess the site and locate previously excavated areas is crucial to an investigation designed this way. Not only can geophysics identify areas that have been previously disturbed, but they can identify new areas to target that have intact cultural deposits. The investigations at 48PA551 accomplished exactly this and set the stage for new and important findings about the Middle Holocene Rocky Mountains.

This study has set the stage for future research and has provided ample evidence that 48PA551 still has much to offer the archaeological community.

Chapter 5 – Obsidian Artifacts at 48PA551: Using Obsidian to Address Land Tenure Strategies Among Hunter-Gatherers of the Rocky Mountains

Site 48PA551 lies at the edge of the Yellowstone Plateau in the foothills of the Absaroka Mountains in an area known as the Sunlight Basin (Frison and Walker 1984). It is nestled along a tributary of the Clarks Fork of the Yellowstone River, which separates the Absaroka Mountains from the Beartooth Mountains and the Beartooth Plateau. An ever-growing body of archaeological work, especially at the higher elevations, has filled in every ecological niche in the region with dots on the map, representing an increasingly holistic view of prehistoric montane occupation. The research of the last few decades continues to push back against false notions about the land that the even the Wilderness Act of 1964 dubbed as "…an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain" (*16 U.S.C. 1131*). The research presented here seeks to build off the efforts of those who have come before to rebuke the narrative and shed light on the past lifeways of human populations who continue to live today.

The Greater Yellowstone Ecosystem (GYE) has provided a wealth of resources to humans in the northwestern Plains and the Rocky Mountains for at least the entire Holocene, if not beyond. The region consistently provided refuge, food, and tool stone for hunter-gatherers from the sage and grasslands of the low basins to the whitebark and limber pine-covered slopes of the mountain peaks. Specifically, the region's volcanic activity has provided some of the richest deposits of volcanic tool stone in the world. Since the early 1990s, researchers have compiled an index of the major obsidian and dacite sources in the GYE (Baumler 1997; Cannon and Hughes 1993, 1997; Davis et al. 1995). Identifying the points of origin for these raw materials has allowed archaeologists to better understand the indigenous use of the materials for at least the last 11,000 years, both within the region and across North America. Rarely do archaeologists have the opportunity to study "who" occupied an archaeological site or landscape they are studying, especially before the Late Prehistoric period. However, sourceable lithic material is one of the ways one has the incredible opportunity to begin to address the "who." This isn't to say that one can identify the tribal affiliation or specific identity of the tool stones procurer or last user, though some have taken up the challenge of tying identity to obsidian users (see Finley et al. (2015) and Scheiber and Finley (2011)). However, sourcing studies can shed light on land tenure strategies, territoriality, geographical connections, seasonal rounds, and reciprocity. Knowing these characteristics of a group gives valuable insight into the minds of those who first laid hands on the stone. In this day and age, we can come incredibly close to truly understanding these aspects of the precontact past with a piece of stone.

In addition to sourcing studies, models of human technological organization have sought to understand the human decisions that lead to the movement of artifacts across a landscape in predictable ways (Schiffer 1972; Binford 1979; MacDonald 2014; Scheiber and Finley 2011). Early studies relied on linear regression models, which assumed there further away from a lithic source one is, the less of that raw material is expected (Renfrew et al. 1968; Renfrew 1972; Reid 1986). Multiple studies brought forth the idea of raw material "influence zones" (or conveyance zones) and suggested that tool stone sources have a geographical area of influence where that source material is dominant and that when one begins to approach another source, there is a point where another zone is encountered (Jones et al. 2003; 2012; McCoy et al. 2010; Smith 2010). Simple least-cost path (LCP) studies use elevation data to find the path between artifact and lithic source that follows a route with the least elevation change. Other researchers have made cost models more robust by introducing other variables. Harvey (2012) created cost-surfaces to model the energy and time costs for round-trip travel from source to sites for major sources in the Wyoming Basin. The cost surface analysis performed by Finley and company (2015) incorporates caloric travel costs for different carrying loads (Brannan 1992), uphill versus downhill travel (Conolly and Lake 2006), and surface roughness (Wheatley and Gillings 2002). Most of these analyses rely on the assumption (as all models do) that primary lithic procurement occurred. In other words, they assume that the individual who entered the artifact into the archaeological record was the individual who traveled to obtain the tool stone at its source. This also assumes that even if the procurer of the lithic material at a given site was directly procured by the same person or group who discarded the artifact, they traveled directly to and from the lithic source to the place of deposition. The models also do not consider other ways in which we know tool stone can travel across the landscape, such as through trade and exchange. This study uses obsidian as a proxy to understand how 48PA551 fits into landscape use, human movement, and settlement patterns in the Middle Holocene Rocky Mountains.

This research uses obsidian data from a single site in the GYE to test existing land tenure and territoriality models based upon the sourcing and subsequent movement of obsidian. As discussed later on in this paper, the existing studies, while on a spectrum, have generally polarized between two major schools of thought. These perspectives (outlined first in Johnson et al. 2004 and improved upon by MacDonald 2014) diverge over whether a single group or multiple groups were operating in the GYE and if they were practicing specific forms of territoriality and land tenure. This study does not seek to debate or reevaluate the models but instead tests them with a single dataset. The models are based upon regional datasets which seek to understand broader patterns of prehistoric activity. The best way to test the validity of each paradigm is to use new data from a site within the region and apply it to each model. With a large enough dataset, this approach, while relatively novel on its own, can significantly add to our understanding of prehistoric lifeways of the GYE.

Obsidian Research in the GYE

The lithic landscape of the GYE, especially as it relates to volcanic sources, is relatively well understood due to almost three decades of dedicated research. The development of energy-dispersive X-ray fluorescence (EDXRF) in the mid-1980s established a new era of volcanic rock sourcing research (Hampel 1984; Hughes 1984; Shackley 1998). This technique significantly increased the diagnostic accuracy of volcanic toolstone sources and greatly improved upon the neutron activation analysis techniques that were used prior (Griffin 1965; Griffin et al. 1969). The earliest studies in the GYE using EDXRF sought to establish the chemical and elemental makeup of known sources (Davis et al. 1995) in addition to synthesizing diagnostic sources that could be used to address land-use and settlement strategies of hunter-gatherers (Baumler 1997; Cannon and Hughes 1993, 1997). These early studies were the first to contribute to our understanding of Paleoindian group mobility patterns by sourcing Agate Basin and Hell Gap point types within Yellowstone National Park (Cannon and Hughes 1993). Further study concluded that during the Paleoindian time period, the occupants of Yellowstone National Park utilized a greater number of obsidian sources than subsequent prehistoric populations in the GYE (Cannon and Hughes 1997). Other early studies and archaeological investigations began to build the GYE obsidian dataset, increase our understanding of obsidian use in the GYE, and identify new sources in the region (Cannon et al. 1993, 1996, 1997; Kunselman 1991, 1994; Kunselman and Husted 1996; Pierce and Morgan 1992; Smith 1999; Thompson et al. 1997; Willingham 1995).

As the obsidian dataset grew and more sources were identified, archaeologists could return to theoretical questions regarding obsidian conveyance and mobility patterns. For example, the University of Montana has contributed significantly over the last decade to obsidian research in the GYE. These studies (over 27 individual projects) have sourced thousands of artifacts to address hunter-gatherer mobility and trade (Adams and MacDonald 2015; MacDonald 2012, 2014; MacDonald and Hale 2013; MacDonald and Nelson 2018; MacDonald et al. 2011, 2012, 2019). In addition to these studies, the University of Montana led projects have also better identified the source locations and use of specific obsidians such as Cougar Creek obsidian (MacDonald et al. 2019), black Park Point (McIntyre et al. 2013), red Park Point (Pfau and MacDonald 2016) and Lava Creek Tuff (Pfau and MacDonald 2016). Beyond these studies, others have also contributed to obsidian research in the GYE covering a broad range of topics, including toolstone choices (Bohn 2007; Park 2010, 2011; Johnson and Reeves 2013; Whitman 2013; Wunderlich 2014) and regional differences in conveyance zones (Finley et al. 2015; Scheiber and Finley 2011; Reckin 2018; Reckin and Todd 2019).

These previous studies all indicate that the GYE was an essential part of prehistoric resource procurement of toolstone and other resources. However, the results of studies specifically concerned with conveyance zones and group mobility appear to be divergent in their conclusions regarding land use and tenure, sharing, and exchange of obsidian. The following pages discuss human technological organization and the specifics that have led to two distinct models concerning hunter-gatherers in the GYE. These models are known as the Single-User Model (SUM) and the Multi-User Model (MUM) (Johnson et al. 2004; MacDonald 2014).

SUM vs MUM

In short, the SUM model suggests that the GYE was utilized by one group of human foragers during their seasonal rounds (Finley et al. 2015; Scheiber and Finley 2011). Scheiber and Finley (2011) argue that the Central Rocky Mountains were part of a "pan-Shoshone" landscape by at least the Late Archaic, if not the Middle Archaic, meaning that one group occupied and utilized a large territory. Their obsidian evidence suggests that there was no widespread migration of Numic speakers during the Late Prehistoric period, indicating a longer-term presence in the region. They explain that obsidian sources from archaeological sites in the Wyoming Basin differ from the Yellowstone Plateau, which indicates highly regionalized settlement patterns and the use of obsidian as a local phenomenon. Given the earlier suggested Numic entrada, the difference between geographic subregions is likely an indicator of early separation of bands, which formalized and intensified in later periods. While the ethnographic evidence shows that the Sheep Eater Shoshone were the primary residents of this region in the historic period (Nabokov and Loendorf 2004), Finley et al. (2015) suggest that the overlapping conveyance zones of the Wyoming Basin and Yellowstone Plateau represent tebíwa, or foraging territories (Smoak 2006) that have been in place for much longer, since the Middle Archaic (5000 to 3500 BP), aligning with Holmer's (1994) estimation of Numic arrival to the area. They postulate that territory contraction can be seen later in the archaeological record by a reduction in obsidian source diversity between the Late Prehistoric Period and Historic period (Scheiber and Finley 2011: 380-385). Overall, the SUM argues that the Numic entrada into the GYE occurred as early as the Middle Holocene, meaning that a single, stable social group claimed the Central Rocky Mountains as their foraging territory, albeit occupied by separate bands.

The other model (MUM) suggests that a variety of distinct forager groups from a number of regions utilized the area around Yellowstone Lake (Johnson et al. 2004; Johnson and Reeves

2013; MacDonald 2014; Park 2010; Park 2011) and beyond (Reckin 2018; Reckin and Todd 2019). MacDonald (2014) presents an argument that shows a diverse number of human forager groups seasonally occupying distinct parts of Yellowstone Lake using lithic raw material diversity and obsidian point of origin studies using EDXRF. Specifically, MacDonald illustrates distinct forager group occupations on the north, east, southeast, and southwest/west shores of Yellowstone Lake, leading to the conclusion that the GYE and, more specifically, Yellowstone Lake, was a "crossroads of multiple tribal and/or band territories" (MacDonald 2014: 156). For example, the eastern shore of Yellowstone Lake likely indicates ties to the Great Plains and Big Horn Basin, while the southeast shore shows more of a connection with the Jackson Hole area. The obsidian results from the southwest and western shores point to connections with the Snake River Plain and Great Basin in eastern Idaho. Overall, these results do not agree with the notion that Yellowstone Lake was the center of a Numic tebiwa, as suggested by Scheiber and Finley (2011).

Reckin (2018; Reckin and Todd 2019) continues to support the MUM in the GYE using obsidian source data, arguing that there is evidence for the existence of multiple socially bounded groups in the GYE, specifically in the Beartooth and Absaroka mountain ranges. Distinct conveyance zones between the mountain ranges were identified from the overrepresentation of Idaho obsidian sources in the Beartooth Mountains, which are preferred to equidistant or closer sources within the GYE (Reckin and Todd 2019: 447). The Absaroka Mountains were shown to have a different obsidian source signature than the Beartooths and had an underrepresentation of the Bear Gulch obsidian, which was overrepresented in the Beartooths, indicating differential access to the source between the areas (Reckin and Todd 2019). The distinction in obsidian sources between mountain ranges again indicates that there is more than one social group operating in the area. Diagnostic artifacts indicate that this persists through the Archaic period. It isn't until the Late Prehistoric that the results begin to align with the findings from Scheiber and Finley's (2011) argument.

Returning to the hypotheses discussed earlier in this dissertation, we can use the SUM vs MUM arguments to better understand land tenure and territoriality scenarios. To review, Cashdan (1983) identifies two mechanisms that human foragers use to control access to resources. The first strategy is perimeter defense, where there is direct competition between groups over space and resources. This scenario means that physical territories are defined, and access to the space and resources within the territories are defended. The SUM aligns with this scenario given the speculation that the Central Rockies and GYE were a single foraging territory occupied by related bands of Mountain Numa as far back as the Middle Holocene (as suggested by Scheiber and Finley (2011) and Finley et al. 2015). Under a Dyson-Hudson and Smith (1978) model, this would mean that the resource base in the GYE was highly predictable and dense and that the access to defined foraging areas would be defended. Only related bands of ancestral Shoshonean peoples would have access to the territories. This is illustrated to some degree in the overlapping conveyance zones identified in Finley et al. (2015: 387).

The second strategy outlined by Cashdan (1983) can be referred to as "social boundary defense," where there is less concern with the direct control of territorial space and resources. In this scenario, foraging areas are larger due to less predictable and sparser resource bases. The foraging ranges become too large to feasibly defend any physical boundary. Therefore, the knowledge of resources is restricted to outsiders instead of the territory itself. On the other hand, knowledge of resources in foraging areas can be shared with other groups. This knowledge is the crux of the idea of social boundary defense. Kelly (2013) applies Winterhalder's (1986) model of food sharing to a group of foragers and indicates that social boundary defense will occur when the intragroup variance of resource returns is high, and intergroup resource base correlation is low. This means that groups in and around the GYE would practice social boundary defense in a situation where other nearby groups have different resource bases and could be called upon for assistance if resource return is highly variable. The MUM fits this scenario as it assumes multiple foraging groups would be operating around the same region and would interact or participate in trade and exchange given the different resource bases. In Reckin and Todd (2019), the connection of the Beartooth Mountains to the Snake River Plain fits the social-boundary defense and MUM models given that the resource base between the two areas is significantly different, therefore making it easier to come to one another's aid during times of hardship.

Data

Previous obsidian sourcing with artifacts from 48PA551 has already been completed by researchers in recent years (Todd and Reckin 2019). These artifacts were from the projectile point assemblage recovered from the initial excavations at the site which were housed at the University of Wyoming Archaeological Repository (UWAR). The results from those investigations are incorporated in this study. In addition to these projectile points, further collections research at UWAR added an additional three obsidian projectiles (recovered from Dr. Frison's office by his suggestion), five early-stage bifaces, one core, and 36 pieces of debitage. During the most recent excavations, only three obsidian tools were recovered, one of which was an ear of a projectile point. All three of these tools and five additional flakes were subject to EDXRF, bringing the total sample size of sourced material to 67 specimens. Forty-four (44) new specimens were sourced through the Geochemical Research Laboratory overseen and operated by Dr. Richard Hughes (Hughes 2020).

Methods

All samples were submitted to the Geochemical Research Laboratory (GRL), directed by Dr. Richard Hughes, now based in Sacramento, California, given his extensive experience with archaeological geochemistry in the GYE. This analysis utilized EDXRF spectrometry to determine the obsidian's major, minor, trace, and rare earth elements. The distinct signatures of the various chemical elements in the obsidian artifacts determined the likely geological source of origin. The analysis was performed utilizing a QuanX-EC™ EDXRF spectrometer by Thermo Electron Scientific Instruments Corporation. The spectrometer was equipped with a silver x-ray tube, a 50 kV x-ray generator, a digital pulse processor with automated energy calibration, and a Peltier cooled solid-state detector with 145 eV resolution at 5.9 keV. Analyses targeted the elements rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb) in addition to generating iron vs. manganese (Fe/Mn) ratios.

Trace element measures are expressed in parts per million (ppm) by weight, and matches between the analyzed artifacts (unknown chemical signature) and known chemical groups are made on the basis of correspondences at the 2-sigma level for the diagnostic elements listed above. The diagnostic trace element concentration values are pulled from previous findings from the GYE in published sources (Anderson et al. 1986; Baugh and Nelson 1987, 1988; Cannon et al. 2001; Glascock et al. 1999; Hughes 1984, 2005, 2007; Hughes and Nelson 1987; Nelson 1984) and unpublished sources on data in Utah and Wyoming obsidian sources (Hughes 1995a, 1995b, 1997; Hughes and Cannon n.d.). The elemental signatures of each artifact were considered diagnostic if the artifact measurements fell within two standard deviations of the mean values for the source standards. Diagnostic elements are concentrations of values that allow for the distinction between sources (Hughes 1993).

Following the results of the EDXRF analysis, the total number of artifacts from each identified obsidian source was subject to a power regression analysis plotted against values derived from a number of variables to assess potential relationships. The values and variables are drawn from the MacDonald et al. (2019) quantitative assessment of GYE obsidian sources. MacDonald et al. (2019) found that low-ranked Yellowstone obsidians were used expediently and closer to the origin source while highly ranked obsidians were curated and used both locally and farther away from the source (as suggested in Andrefsky 1994 and MacDonald 2009). The quantitative assessment compared major volcanic toolstone sources in the GYE based upon 10 separate attributes. The attributes included the number of projects in which a specific obsidian source was identified, the total count of artifacts, the average maximum distance from site to geologic source, the total area (km²) a source is found, distance to a major river, elevation, Fe/Mn ratio, purity, color, and aesthetic. These attributes were then used to conduct eight z-score analyses on seven different sources of obsidian; Obsidian Cliff, Bear Gulch, Cashman Dacite, Cougar Creek, Lava Creek Tuff, Red Park Point, and Park Point obsidians. The z-score analyses measured use, demand, abundance, access, quality, aesthetic, and a total weighted z-score of all analytical categories. The findings suggest that indigenous peoples of Yellowstone National Park likely went out of their way to obtain Obsidian Cliff and Bear Gulch obsidian as well as Cashman dacite. Sources including Cougar Creek, Lava Creek Tuff, and the Park Point sources were less desirable and used more expediently, and acquired locally. This analysis approaches precontact decision making about toolstone and transport from a unique perspective providing an opportunity to further assess obsidian sources at sites across the GYE.

This analysis uses the elevation, distance to a major river, number of projects found, Fe-Mn ratio, purity index, and total area (square kilometers) of obsidian sources represented at

48PA551 to perform the regression analysis. The regression analysis produces a curve from which the expected number of artifacts at 48PA551 can be derived. A power regression was selected in lieu of other regression functions, given that variables such as distance to source are incremental variables related to the quantity of observed obsidian. Additionally, power regression analysis assumes that the response variable is proportional to the exploratory variable (raised to a power) which follows the methods outlined in Reckin (2018) and Reckin and Todd (2019).

The expected values produced from the power regression curves were then used to compare observed values using Chi-square tests. This approach follows the thinking of Reckin (2018) and Reckin and Todd (2019), who used straight-line distance to assess the implications of obsidian sources present at sites in Absaroka and Beartooth Mountains. In their analysis, chi-square tests were completed to compare the quantities of obsidian by each source from a number of sites with the expected quantities calculated by the model of best fit (represented by power regression) based on the average distance to each source. The analysis in this dissertation takes the approach a step further and seeks to determine if the variables used in MacDonald et al. (2019) may explain the reasons for obsidian choice. The results of obsidian source, regression, and chi-square analysis are presented in the following section.

Hypotheses

The archaeological assemblage at 48PA551, specifically obsidian artifacts, provides a unique opportunity to test the proposed arguments of the SUM and MUM in the GYE and provide a glimpse into the land tenure and territoriality strategies of the Middle Holocene. The hypotheses discussed earlier in this dissertation are tested by two different analyses; EDXRF and isotope analysis. The obsidian EDXRF results use the obsidian signature at the site to determine the social conditions of the occupants at the site. The following hypotheses modify those presented earlier to focus solely on the obsidian results to interpret how the site fits into the SUM vs. MUM model and to assess potential land tenure strategies.

The initial hypotheses identified one scenario where the site was occupied by members of a single social group who aggregate together during the winter. This strategy is described by Shimkin (1947), who notes that the Eastern Shoshone were known to disperse in the summer and aggregate during the winter months. This strategy also falls within the arguments of Finley et al. (2015) and Scheiber and Finley (2011) and the Single User Model of the GYE by members of the Mountain Numa. In this scenario, the obsidian sources will not be highly variable and should reflect a single social network or conveyance zone. There will be little spatial segregation of obsidian sources across the site because only a small number of obsidian sources will be present. If some spatial segregation of sources is measured, it likely represents different small family groups or related bands. If the SUM was indeed in place by the Middle Archaic, then access and knowledge of obsidian sources should not be restricted. The highest quality, closest, and most accessible sources should dominate the assemblage, as there would be no need to rely on lower-quality toolstones.

Another scenario could be that the site represents a group that operates under conditions of social boundary defense and that 48PA551 represents a location and group that differs from others operating in the region. This site lies near the boundary between the Absaroka and Beartooth mountain ranges, so it may fall within one of the identified social boundary defense zones outlined in Reckin (2018) and Reckin and Todd (2019). In this scenario, the obsidian sources should indicate some form of differential access to toolstone and identify different social networks between distinct groups of human foragers. This means that some sources will be overrepresented compared to sources that one would logically expect to see in the assemblage (similar to that identified in Reckin and Todd (2019)). The obsidian sources will show distinct social connections representing obsidian conveyance zones within and potentially outside the GYE.

The patterns of obsidian data and the results of the Chi-square tests should provide evidence for one of the land tenure and social organizational models discussed above. The data at 48PA551 will reflect a Single User Model (SUM) and a single, pan-GYE territory if obsidian doesn't exhibit controlled access to the lithic source. This means that sources from within the GYE should be represented more than those outside of the region, especially Obsidian Cliff given its high quality and proximity to the site (100 km). If the region is indeed part of a single social network or if it is part of a territory (similar to a pan-Shoshone landscape argued by Scheiber and Finley (2011)) then there would be little need for outside sources like those found on the Snake River Plain. Additionally, one would expect higher-quality and more accessible obsidian (as measured by MacDonald et al. 2019) to dominate the sourceable assemblage if there are no restrictions on who can access the resource. This would be seen in the data by similar expected and observed values based on the power regression from straight line distance to the source. In addition, the expected values of obsidian artifacts should also be similar to the observed values based on other factors MacDonald and colleagues (2019) used in their valuation of GYE obsidian sources. This includes access (proximity to major river and elevation), quality (Fe-MN ratio and purity index), and availability (number of projects found and source area). In essence, the representation of obsidian sources from this scenario should be reflective of a single group collecting (or trading for) obsidian based upon solving contingency issues. In other words, the obsidian that is the best and easiest to acquire should be represented more than the lower quality and harder to access sources.

If reciprocity and access to resources like obsidian are more strictly controlled, then obsidian artifacts at 48PA551 will not represent logical or contingency-based acquisition of raw materials. Instead, artifacts may indicate a Multiple User Model (MUM) of the region by an overrepresentation of obsidian sources that are outside or on the periphery of the GYE. External obsidian sources may also indicate that the site's residents are part of a social network that has unique access to a different resource base from a group outside the GYE. This would reflect something similar to a social boundary discussed above. This also means that the higher quality and more available or easier to access sources will not be as well represented. Expected values from the power regression formulas in this scenario will not necessarily align with the observed values of obsidian artifacts. This includes all comparative categories, including distance to the source, quality, access, and availability.

Results

Of the 23 artifacts sourced in a previous study (Todd and Reckin 2019) and the 44 samples submitted for this analysis, 67 samples were analyzed. Figure 5.1 breaks down the EDXRF results by obsidian source, artifact type, and dataset. The results from the previous study and this study closely mirror one another. When combining the two studies, the majority of the artifacts were made from Lava Creek Tuff (45/67 or 67%), while the remainder of the artifacts with known sources were from Obsidian Cliff (17/67 or 25%) and Bear Gulch (1/67 or 1.5 %). Three artifacts were from unknown obsidian sources, while a single analyzed artifact was not obsidian (black chert).

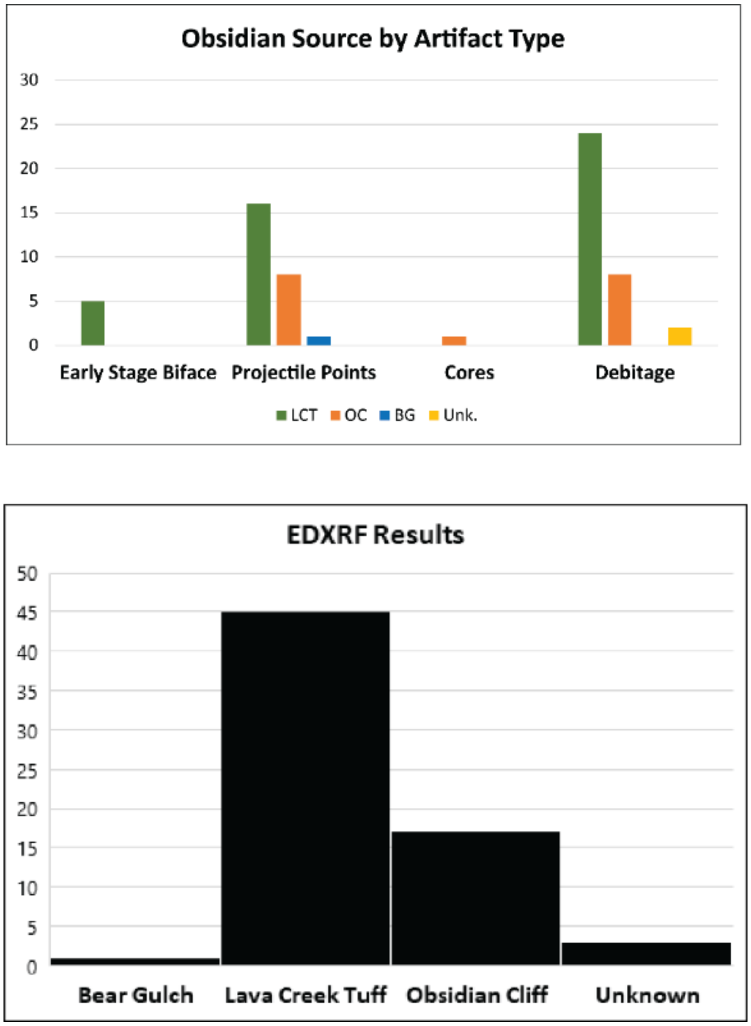


Figure 5.1. EDXRF results by source and artifact type.

The range of Fe/Mn and Zr/Nb ratios for Lava Creek Tuff is known to overlap with Conant Creek obsidian, which contain Ba in the range of 400-500 ppm (Hughes 1997). However, none of the artifacts in this analysis contain Ba in that range, meaning that they securely fall within the diagnostic signature for Lava Creek Tuff. Two specimens have ratio values that subsume them into the Lava Creek Tuff group, but primary data indicates that they have Zr ppm values that are greater than Rb. This is usually not the case for the majority of Lava Creek Tuff or Obsidian Cliff obsidian based upon the current reference collection and geologic standards. Hughes (2020) opted to classify these artifacts as originating from an "unknown" source, given that the Zr and

Rb values fall outside a known source. However, he speculates that additional geological sampling may indicate that the artifacts align with a new, artifact-quality tuff variant with the known Lava Creek Tuff area. At this point, there is no compelling empirical data and the source remains unknown.

Three specimens submitted for the analysis were determined to be too small to generate reliable quantitative composition estimates. However, using protocols outlined in Hughes (2010), Hughes (2020) was able to semi-quantitatively determine sources. Two of these small specimens fall within the Fe/Mn vs. Zr/Nb ratio parameters of Lava Creek Tuff, while the remaining small specimen conforms to the profile of Obsidian Cliff obsidian.

The obsidian artifact type does not break evenly between sources (Figure 5.1). Interestingly, all early-stage bifaces (n=5) were sourced to Lava Creek Tuff, while the only core sampled was sourced to Obsidian Cliff. Of the 26 projectile points sourced, 16 were sourced to Lava Creek Tuff, twice as many as were sourced to Obsidian Cliff (n=8). The remaining two projectiles were sourced to Bear Gulch and an unknown source. Only eight pieces of debitage were sourced to Obsidian Cliff, while 24 flakes were from Lava Creek Tuff. Two pieces of debitage were from an unknown obsidian source. Almost all of the recovered obsidian debitage were tertiary flakes lacking cortex and likely indicate tool maintenance and resharpening activities. One black chert flake was mistaken for obsidian and could not be sourced.

All regression formula and chi-square results are presented in Figures 5.2 and 5.3. The first chi-square analysis was conducted on the expected and observed number of obsidian artifacts based upon the straight-line distance to the source. In this instance, LCT is significantly overrepresented (45 observed versus 13.51 expected) while OC is underrepresented (17 observed versus 39.86 expected) based upon the expected values from the power regression. The chi-square results indicate that the difference between the observed and expected values are significant at the .05 confidence level ($x^2 = 86.71$, df=2, $p<0.0001$).

Looking beyond straight-line distance (from site to source) for other potential explanatory variables, the same analysis was conducted, and based on the area (km^2, indicating availability), the number of GYE projects found (also as an indicator of availability), the Fe-Mn ratio (quality), and the distance to a major river (km, indicating access). The regression formula testing obsidian source representation by the distance of the source to a major river (in km) produced the most similar observed and expected values. However, the values are still some ways apart. For example, Lava Creek Tuff is still overrepresented (45 observed compared to 31.23 expected), but values are much closer together and represent the dominant category. Obsidian Cliff and Bear Gulch are both eight kilometers further from a major river and have much smaller predicted values (both expected at 3.13 artifacts). The results of the chi-square analysis indicate that the relationship between the values is statistically significant at the .05 confidence level ($x^2 = 66.37$, df=2, $p<0.0001$).

The regression formula based on the Fe-Mn ratio seeks to evaluate obsidian choice based on quality, where the higher the ratio is, the better the quality of obsidian. Obsidian Cliff has the highest ratio of the three obsidians represented at the site, with Lava Creek Tuff in the middle and Bear Gulch with the smallest value. Again, Lava Creek Tuff has a much higher observed value than expected (45 versus 13.51), while Obsidian Cliff falls short of the expected value (17 versus 29.18). The expected and observed values differences are also statistically significant at the .05 confidence level with $p<0.0001$ ($x^2 = 224.05$, df=2).

The comparison of expected and observed values of obsidian artifacts based upon the area (in square kilometers) of a source attempts to evaluate availability. It should be noted that these area values are taken from MacDonald et al. (2019) and represent an approximation of a known source. The source material used in EDXRF is usually from a single area in the source and does not necessarily reflect the chemical signature of the entire area. The expected values of Lava Creek Tuff and Bear Gulch obsidians based on their total area align quite well with the observed values where LCT observed 45 with an expected value of 54.95 and BG observed 1 with an expected value of 2.98. However, based on this power regression, the expected number of Obsidian Cliff artifacts was remarkably higher than the observed values (17 observed, 182.5 expected). The relationship between observed and expected values for the total area was statistically significant at the .05 confidence level ($p<0.0001$, x^2= 154.19, df=2).

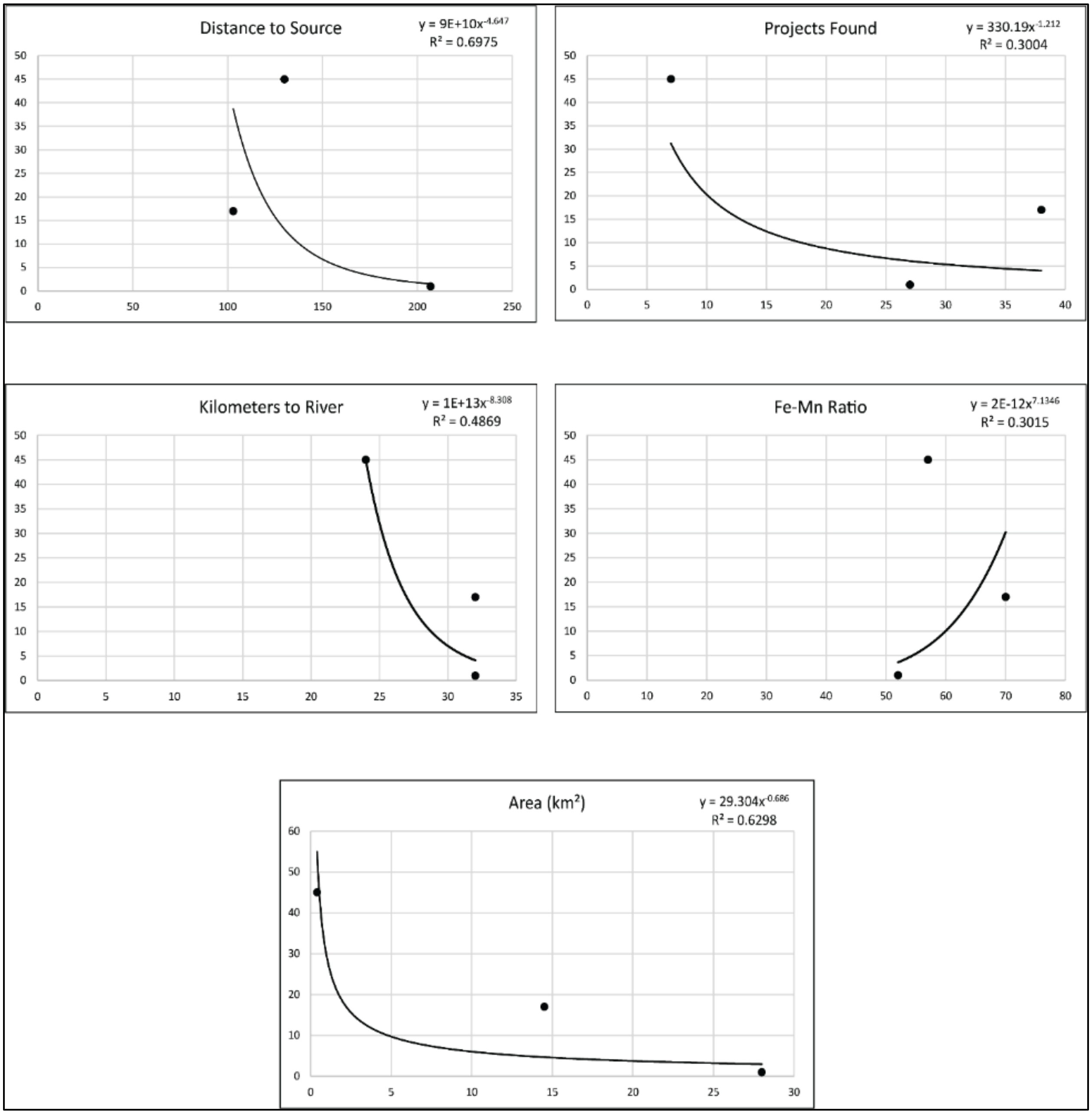
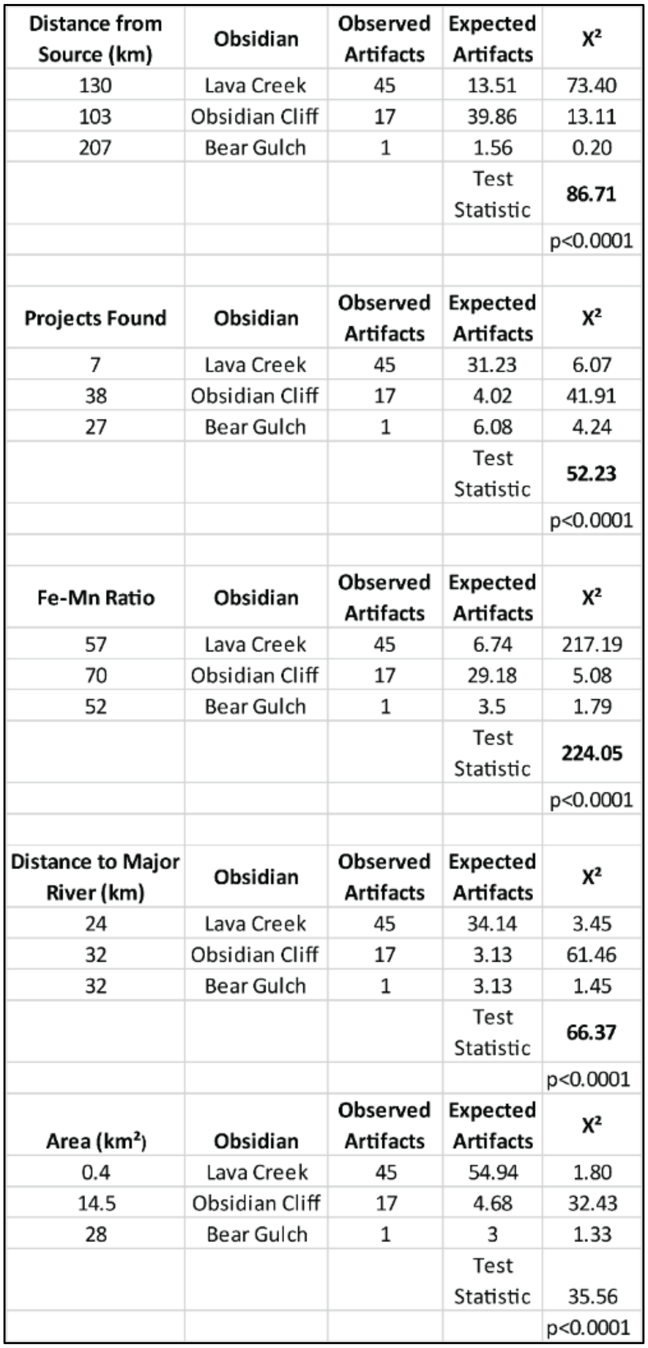


Figure 5.2. Power regression plots and formulas. Note that Y-axis is number of expected artifacts while X-axis is the variable in chart title.



Distance from Source (km)	Obsidian	Observed Artifacts	Expected Artifacts	X²
130	Lava Creek	45	13.51	73.40
103	Obsidian Cliff	17	39.86	13.11
207	Bear Gulch	1	1.56	0.20
			Test Statistic	**86.71**
				p<0.0001

Projects Found	Obsidian	Observed Artifacts	Expected Artifacts	X²
7	Lava Creek	45	31.23	6.07
38	Obsidian Cliff	17	4.02	41.91
27	Bear Gulch	1	6.08	4.24
			Test Statistic	**52.23**
				p<0.0001

Fe-Mn Ratio	Obsidian	Observed Artifacts	Expected Artifacts	X²
57	Lava Creek	45	6.74	217.19
70	Obsidian Cliff	17	29.18	5.08
52	Bear Gulch	1	3.5	1.79
			Test Statistic	**224.05**
				p<0.0001

Distance to Major River (km)	Obsidian	Observed Artifacts	Expected Artifacts	X²
24	Lava Creek	45	34.14	3.45
32	Obsidian Cliff	17	3.13	61.46
32	Bear Gulch	1	3.13	1.45
			Test Statistic	**66.37**
				p<0.0001

Area (km^2)	Obsidian	Observed Artifacts	Expected Artifacts	X²
0.4	Lava Creek	45	54.94	1.80
14.5	Obsidian Cliff	17	4.68	32.43
28	Bear Gulch	1	3	1.33
			Test Statistic	35.56
				p<0.0001

Figure 5.3. Chi-square results.

The vast majority of the samples were from the original excavation collection and made up 55 out of the 57 samples. As discussed in Chapter 4, the provenience from the original excavations is not as well understood from the records as originally hoped. However, the approximate locations of prior excavation allow for the plotting of obsidian sources across the site and provide a general overview of the distribution. Across all excavations at the site, 55 of the sourced obsidian artifacts have enough horizontal provenience information to plot them to their excavation block location. Figure 5.5 illustrates the general horizontal distribution of obsidian sources. Overall, there does not appear to be any significant horizontal segregation of toolstone sources. However, though the sample size is small, areas on the periphery of the center portion of the site tend to have slightly more toolstone source diversity. The small area across the creek (which wasn't re-excavated in 2018) contains the only artifact sourced to Bear Gulch.

The vertical distribution of obsidian sources was also assessed, though less information was understood about the vertical provenience of the originally excavated artifacts. Of all the sourced artifacts, only 47 had vertical provenience information. The vertical relationship of obsidian sources is plotted in Figure 5.4 at 10cm levels. Most of the sourced objects were found in the first few levels up to 30 cm below the surface before a significant dropoff occurred. A slight pulse of Obsidian Cliff artifacts occurs between 40 and 50 cm below the surface, which is the only depth that works counter to the overall decline in the number of obsidian artifacts.

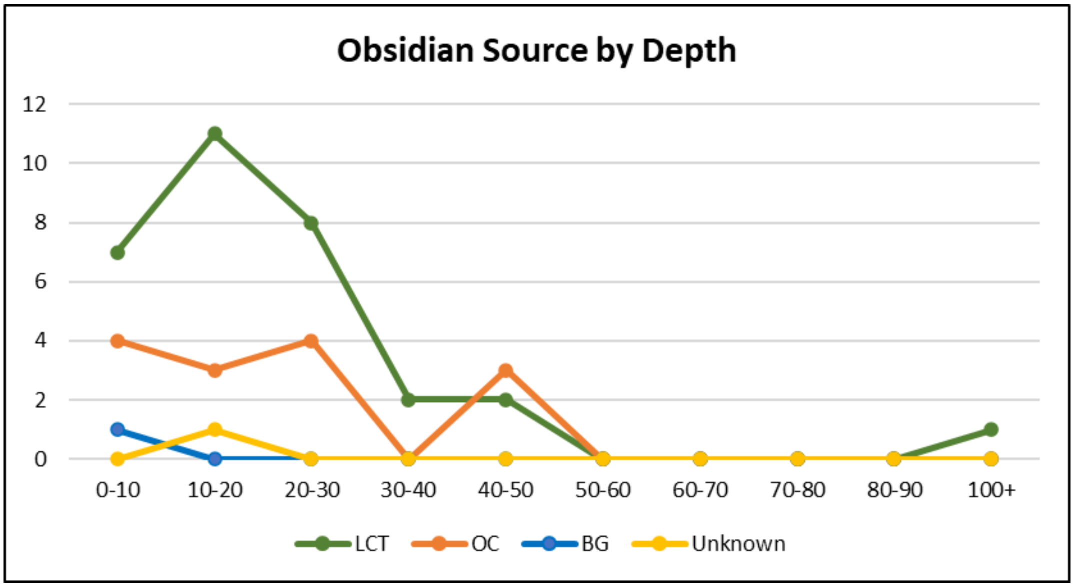


Figure 5.4. Obsidian source by depth.

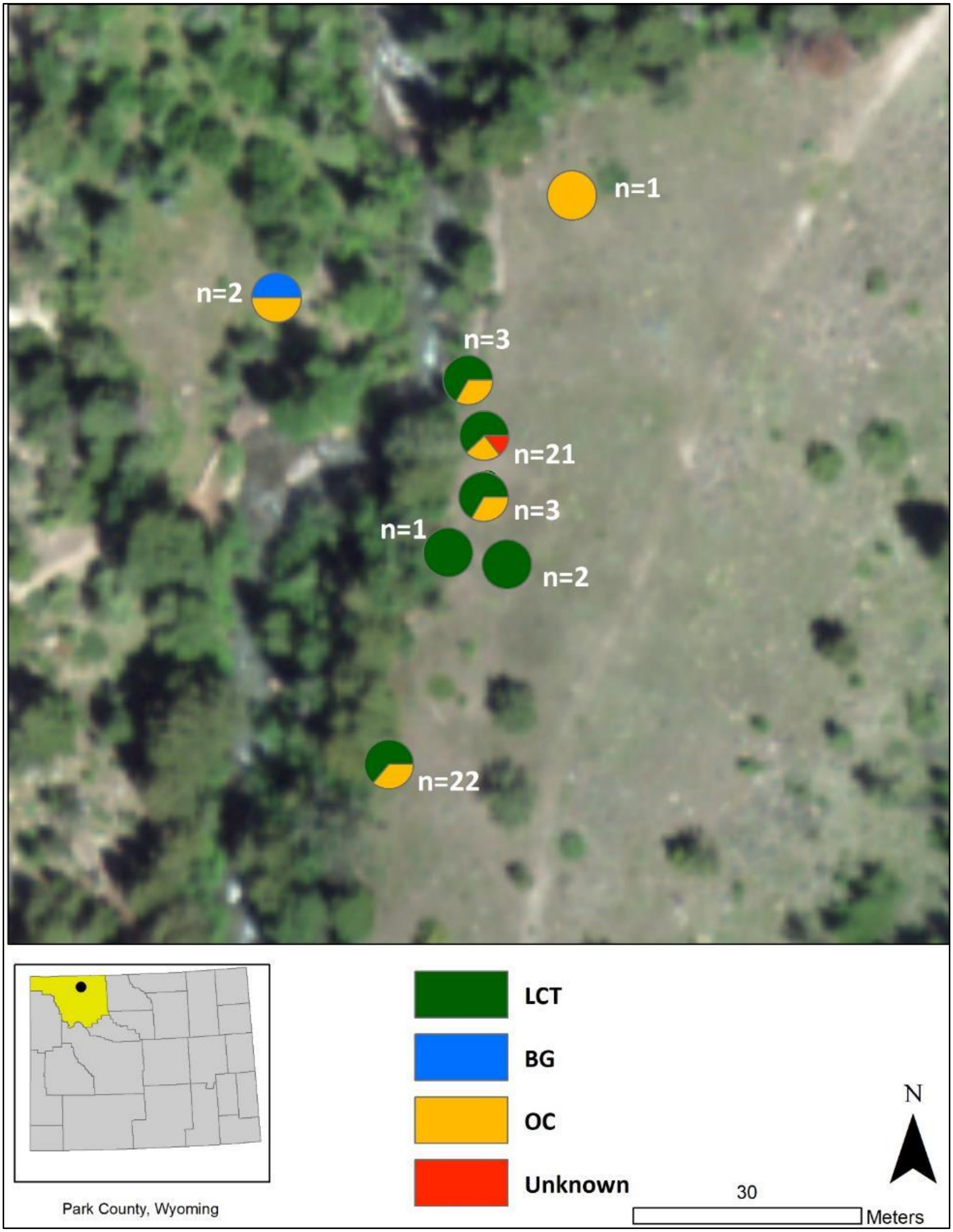


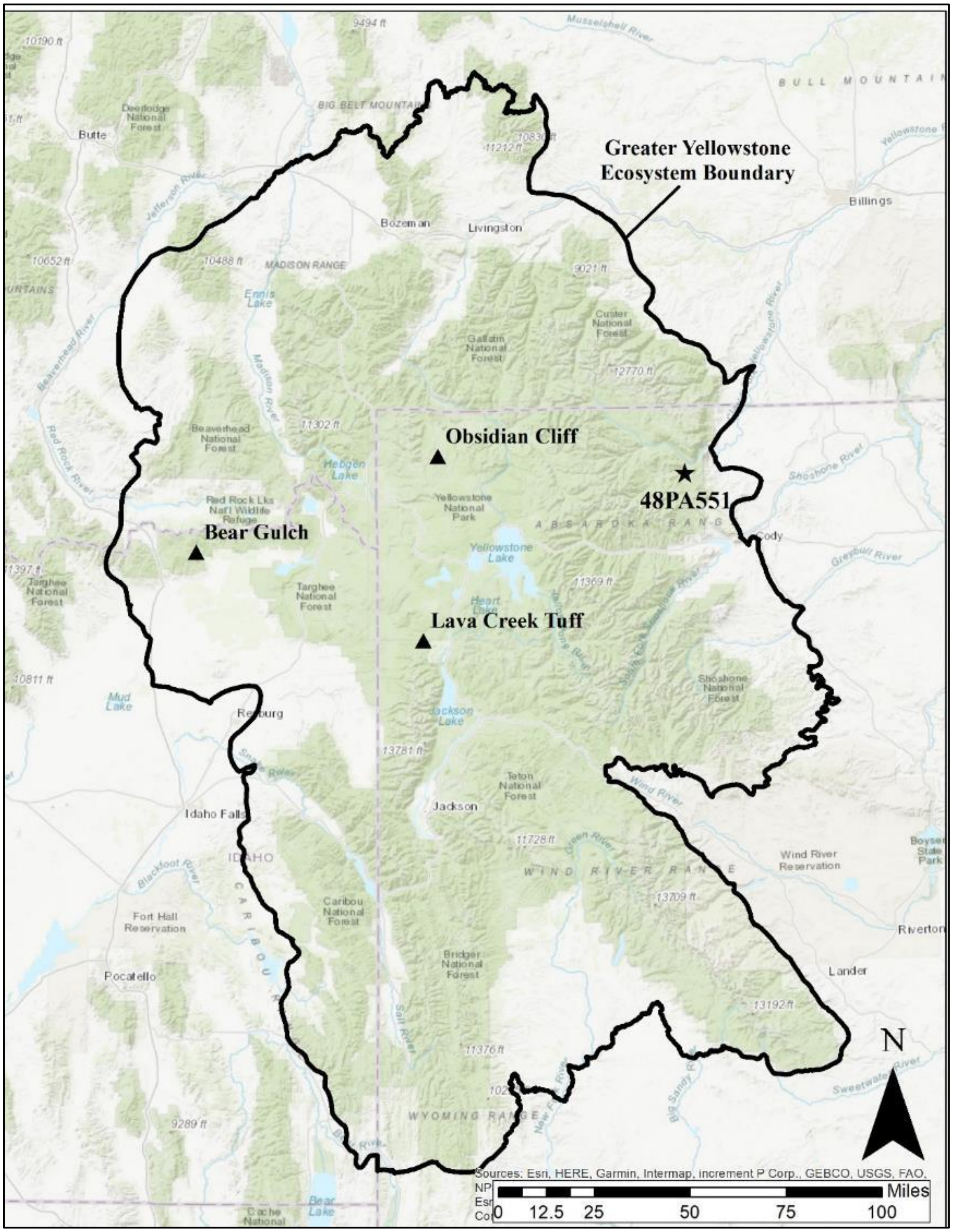
Figure 5.5. Horizontal distribution of obsidian source at 48PA551.

Discussion

The results of the obsidian sourcing analysis proved to be surprising in a number of ways. The dominance of Lava Creek Tuff obsidian is surprising especially given the geographic relationship of 48PA551 and the known diagnostic source of Lava Creek Tuff near Grassy Lake Reservoir. The straight-line distance between the source and the site is approximately 130 km, while Obsidian Cliff is 100 km away. Looking beyond the mere straight-line distance, if the obsidian was acquired directly by occupants of the site, the route to the southern border of Yellowstone National Park where Lava Creek Tuff is located is not straightforward. Many mountain ranges, passes, rivers and valley bottoms are located along any supposed travel route. While the route to Obsidian Cliff isn't exactly straightforward either, the general topography in between empirically appears to be much less daunting.

The diagnostic chemical composition of Lava Creek Tuff is sourced to a single location near Grassy Lake Reservoir, Wyoming, suggesting a relationship to the southwestern part of the Yellowstone Plateau. The presence of a single artifact from Bear Gulch in the Centennial Mountains of northeastern Idaho also suggests a relationship to the same area. However, the geologic formation of Lava Creek Tuff is understood to be found across a much broader area, which should be taken into account when assessing the distance between a site and tool stone source. For example, during a field project, Pfau and MacDonald (2013) located a new outcrop of Lava Creek Tuff obsidian in the Lewis River valley. Figure 5.7 indicates the extent of the Lava Creek Tuff formation, which forms a ring in the southwestern part of Yellowstone National Park as a result of an eruption event approximately 600,000 years ago. While the entire formation may not contain knappable obsidian or any obsidian at all, there is still the chance that the obsidian could have been procured from a much closer but yet unknown source location.

From the data presented in Figure 5.7, the closest possible location for such as source could be a mere 45 kilometers from 48PA551.



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NP Esr Co

Figure 5.6. Locations of obsidian sources identified in this study.

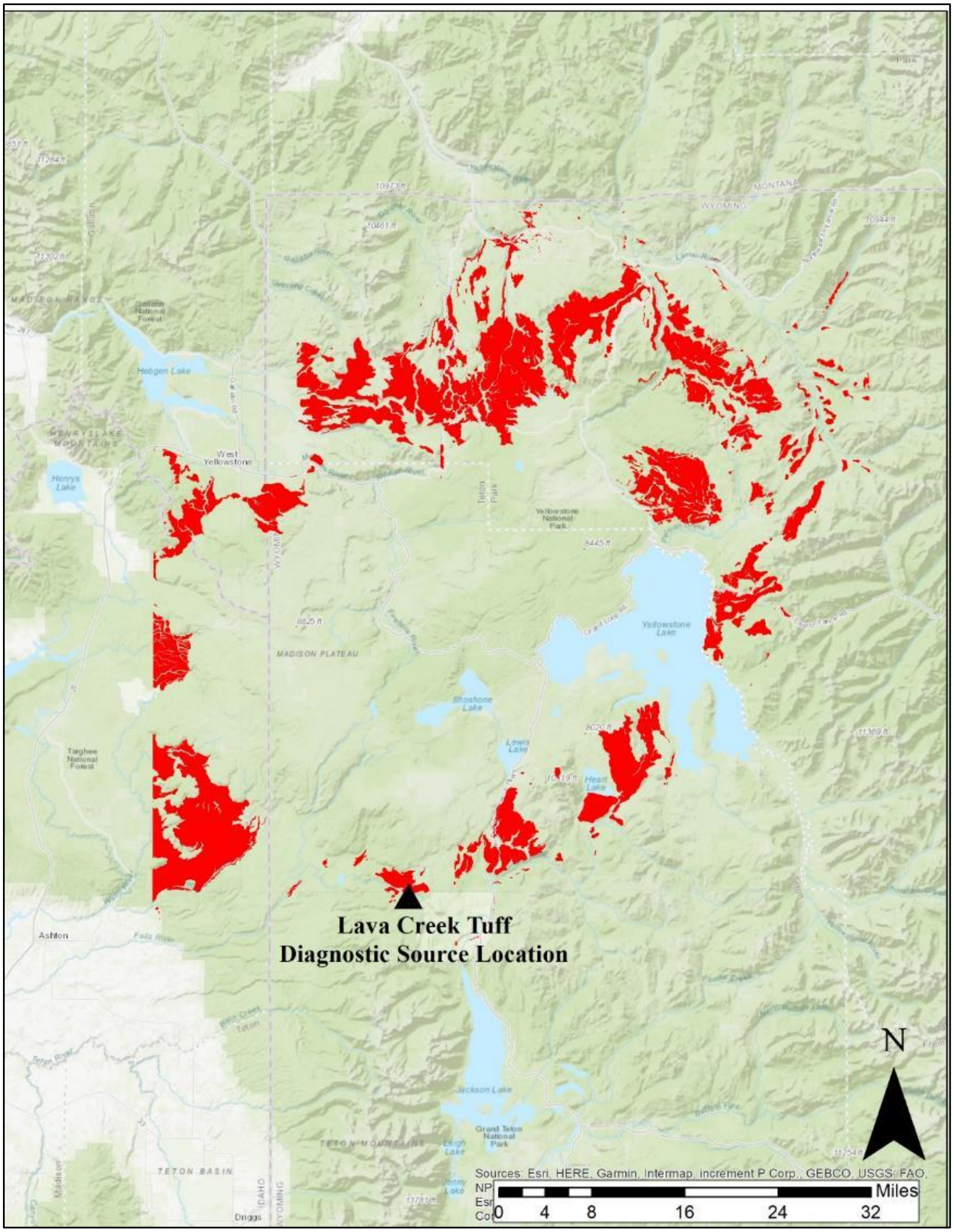


Figure 5.7. Distribution of Lava Creek Tuff formation (NPS Geologic Resources Inventory 2020).

Looking beyond the distance between sources, the dominance of Lava Creek Tuff is intriguing for a number of other reasons. In almost every regression analysis and chi-square test, Lava Creek Tuff was overrepresented, and the differences between observed and expected values were statistically significant. The variables used in the statistical analysis mostly represent practical, contingent-based issues for toolstone collection. Basically, it appears that Lava Creek Tuff is not desirable enough to seek out over other toolstones, and yet it dominates the assemblage at the site. MacDonald et al. (2019) score this obsidian source very low across most categories compared to Obsidian Cliff and Bear Gulch obsidian. The study concluded that Lava Creek obsidian is low in abundance, quality, and aesthetic and that low-ranked toolstones like this are usually collected in a casual or expedient manner (MacDonald et al. 201: 173). Usually, hunter-gatherers did not travel long distances to quarry toolstones such as Lava Creek and were instead potentially obtained during other resource acquisition or social events as identified in Binford (1979) and others (Gould and Saggers 1985). MacDonald and colleagues (2019) identified that their assessment of Cougar Creek likely fell into this category and was a toolstone embedded into a broader cultural system of seasonal rounds and resource acquisition. Overall, it seems likely that the dominant presence of Lava Creek Tuff obsidian at 48PA551 cannot be explained by practical reasoning, given that other toolstone choices are far superior and more readily available.

With the results and assessment above in mind, we can return to the theoretical implications and hypotheses outlined earlier. It seems that the tested explanatory variables for obsidian choice do not explain the volcanic toolstone assemblage at the site. Instead, we can analyze the results within the framework and test expectations of both the SUM and MUM of the GYE. If the SUM represents the social conditions of the GYE as far back as the Middle Archaic, then the occupants at 48PA551 would be part of a foraging band of ancestral Shoshonean group whose tebiwa was located in the northern reaches of the GYE. As a reminder, this would also likely reflect stricter territoriality and perimeter defense of the region. If these social conditions and land tenure strategies were the cases, toolstone sources within the northern foraging territory identified in Finley et al. (2015) would be freely available to hunter-gatherers. Higher quality obsidian, especially sources that are closer, should dominate assemblages if no access restrictions are in place. However, the obsidian sourcing results at 48PA551 resoundingly do not reflect these conditions.

Instead, the results closely align with the MUM and social conditions that support social boundary defense. For example, as discussed previously, volcanic toolstones do not appear to be acquired as a result of simple practical and logistical strategies. Given the lower amount of higher-quality obsidians at the site, it appears that those at 48PA551 did not have full access to Obsidian Cliff. The potential lack of full access and the small number of artifacts could indicate that physical access to Obsidian Cliff was not freely available and that artifacts were instead acquired indirectly through trade. Whatever the case may be, it appears that the human foragers at the site in the Sunlight Basin may have been from a different social group than others who had better access to Obsidian Cliff obsidian. This would align with the expectations from social boundary defense, meaning that even though the foragers had acquired Obsidian Cliff toolstone, it was secondary procurement, and access to the source was restricted. Instead, the hunter-gatherers may have relied on access or social connections in the southwestern part of Yellowstone National Park and even towards the Snake River Plain.

The known, toolstone quality source of Lava Creek obsidian and Bear Gulch obsidian located farther south and west than Obsidian Cliff may indicate that there is a distinct connection between 48PA551 and these areas. Two different scenarios, both of which support a MUM and social boundary defense, could have been at play. First of all, as mentioned in MacDonald et al. (2019), Lava Creek Tuff obsidian procurement could occur in a similar fashion as the authors suggested Cougar Creek obsidian was gathered. Procurement of these obsidians could be wrapped up in seasonal foraging rounds or movement for social gatherings of aligned groups. This would mean that the foragers would travel south and west at certain times of year as part of their entrenched cultural system, similar to that outlined in Binford (1979). If part of the journey was to trade and interact socially with other groups, the implications would mean that one, multiple groups are indeed using and interacting within the GYE, and two, that the groups likely come from different resource bases and could represent intergroup resource sharing, a manifestation of social boundary defense discussed in the hypotheses.

Another scenario could be that there was no physical journey to this part of the GYE and that instead, obsidian was obtained through trade. If the connection to the southern part of the park and the northern edge of the Snake River Plain were real, the resource base would be much different than that at 48PA551. Exchange under social conditions of social boundary defense would be advantageous to each group, especially if those at site 48PA551 did not have full access to the high-quality obsidian at Obsidian Cliff. They could trade for obsidian that aligned groups had access to, namely Lava Creek Tuff. The large quantity of mountain sheep and mule deer remains at the site means that the group had lucrative access to a resource that others might not, opening up the possibility for trade and exchange.

There is an obvious indication that the obsidian recovered at site 48PA551 does not reflect what one would logically expect from the site's location or from what we know about other obsidian sources in the GYE. Given that the obsidian represented at the site doesn’t include the expected quantity of Obsidian Cliff obsidian, social conditions and group connections likely influenced the access to obsidian sources in the GYE. It is likely that this influence resulted from the differential connections and land tenure strategies from multiple groups operating within the GYE.

Conclusion

This study provided an important opportunity to test a series of established landscape-scale models regarding obsidian procurement and conveyance, Middle Holocene social conditions, and land tenure strategies. These models were developed using ethnographic accounts, theoretical contributions from behavioral ecology, and from thousands of sourced artifacts representing an incredible archaeological effort over the past three or more decades. The excavations at 48PA551 recovered a large lithic assemblage, including obsidian artifacts, which allow for the robust testing of these models.

First, the obsidian assemblage from 48PA551 was used to address the Single User Model and Multiple User Model that have been the subject of debate in the GYE. The results appear to favor the Multiple User Model as outlined and argued by Johnson et al. (2004) and MacDonald (2014). The data reflects that the occupants of 48PA551 likely did not have free access to higher quality obsidian sources such as Obsidian Cliff in the northern part of Yellowstone National Park. Instead, lower quality obsidian, as assessed by MacDonald et al. (2019), known as Lava Creek Tuff obsidian, was the dominant obsidian in the assemblage. The lack of access to certain sources and likely connections to the southern part of the park and eastern part of the Snake River Plain indicate that more than one group was operating in the GYE and that socio-economic and political ties result in differential access to resources.

The apparent restriction to certain obsidians and reliance on obsidians in other geographic areas of the GYE may result from social conditions suppporting social boundary defense. Physical territory may not have been defended, as Obsidian Cliff obsidian is still present at

48PA551, but procurement of higher quality obsidian appears to have been more difficult than lower-ranked toolstones. The lower-ranked Lava Creek Tuff obsidian and the single artifact from the high-quality Bear Gulch obsidian may indicate that the human foragers looked to other groups farther south and west for obsidian toolstone. This connection identifies a series of potential conveyance zones and social boundaries between groups, resulting in the reliance on obsidians other than Obsidian Cliff.

The implications of this research indicate that in the Middle Holocene, multiple groups of hunter-gatherers operating within the GYE. These groups appear to have operated under certain social conditions that led to the formation of different social groups and trade networks that restricted access to and the sharing of resources to a certain degree. The restrictions likely played out as social boundary defense rather than physical defense of territory. Obsidian artifacts play an important role in assessing these strategies and social conditions but do not represent the only way to address these questions. Obsidian artifacts only represent a small percentage of the total lithic assemblage at 48PA551 and other sites. Future research needs to take into account other toolstone sources that could provide further clarity on the ideas presented in this chapter. Furthermore, refined provenience on original artifacts and features may provide further clues about the site structure and distribution of obsidian across 48PA551. A more robust spatial analysis will be crucial to understand any potential social variability within the site itself.

Overall, this study will be useful to other researchers and provide a roadmap on how excavated sites can test the models and theories used to address hunter-gatherers in the GYE. In addition, the obsidian sourcing completed in this study adds to the ever-increasing obsidian dataset that will continue to be used in regional studies. Finally, this study has raised more questions about 48PA551 and the Middle Holocene GYE, setting the stage for future research and collaboration.

Chapter 6 – Hunting Strategies at 48PA551: Using Stable Isotopes to Assess Mortality Events of Mule Deer

Mule deer (*Odocoileus hemionus*) are found in archaeological assemblages throughout the west, especially in arid environments like the Great Basin. Archaeological sites throughout northwest Wyoming also continually contain mule deer in the recovered faunal assemblages. However, though mule deer are consistently in archaeological collections, the sheer number of remains at 48PA551 with a minimum number of individuals (MNI) over 50 makes the site unique as a mule deer-focused winter base camp (Frison and Walker 1984). The focus on mule deer in this chapter does not mean that other large game were not well represented at the site. The original excavations recovered a substantial number of bighorn sheep (*Ovis canadensis*) with an MNI of 16, in addition to elk (*Cervus canadensis*, MNI=2), and bison (*Bos bison bison,* MNI=1). This chapter focuses on the mule deer assemblage, given the obvious focus and preference by hunter-gatherers at the site.

The main goal of this section is to assess mule deer hunting strategies using isotopic signatures from tooth enamel bioapatite to differentiate attritional or catastrophic harvest scenarios of mule deer. The notion of harvest events at archaeological sites has received considerable attention in the past, especially at sites containing larger bonebeds (e.g., Davis et al. 2000; Fenner 2008, 2009; Frison 2000; Hill 2002; Lubinski 1997, 2000; Todd et al. 1992, 2001; Widga 2004). In the past, separating these harvest event scenarios has been completed using herd demographics and seasonality, determined by tooth eruptions and/or wear patterns (Frison 1978; Frison and Reher 1970; Todd et al. 1992). However, as stated in Fenner (2009), this approach has proved controversial and, at times, unreliable (for critiques, see Caughley 1974; Lubinski 2000b; Lyman 1987; Steele 2003; Whittaker and Enloe 2000). In short, tooth eruption and wear analysis as a proxy for seasonality can at times prove uncertain and run into reliability and validity issues depending on the technique used in the analysis (Lubinski and O'Brien 2001; Miller et al. 1999). Creating herd demographic and age profiles from a bone bed may also prove problematic, especially if the target animal is migratory. The deposition of bone beds may form from kill events over several years with little stratigraphic separation if herds consistently migrate through a particular area (Hill 2002; Lubinski 1997; Lubinski and O'Brien 2001). Lyman (1987), for instance, discusses the need for a sample size of at least 30 individuals in order to reliably infer the mortality of cervid populations such as mule deer. The original interpretation of mule deer mortality events at 48PA551 (Simpson 1984) was only based on population dynamics, though the sample size did exceed Lyman's (1987) suggested sample size. Nonetheless, another line of evidence is needed in conjunction with population dynamics to truly understand the mortality of the mule deer assemblage at 48PA551. Instead of relying solely on faunal analysis, this chapter follows Fenner's (2008, 2009) logic and others (Hoppe 2004; Widga 2004) and uses isotopic ratio variability to provide another line of evidence for harvest scenarios beyond just herd demography and seasonality data.

However, stable isotope data applies to far more than simply differentiating hunting strategies. The data can be used to assess questions of animal diet, animal migration, plant communities, paleoclimate, and prehistoric ecological conditions, which have implications beyond the field of archaeology (Rundel et al. 1998; Ambrose and Katzenberg 2000; Ehrlinger and Cerling 2001; Ehrlinger et al. 2005; Cannon 2007, 2008). Understanding the ecological conditions of an archaeological site through isotope data is crucial for contextualizing hunter-gatherer subsistence and settlement strategies. This chapter finds the important intersection between archaeology, ecology, and modern wildlife management, recognizing that interdisciplinary approaches are increasingly intertwined in modern research.

Stable Isotope Background

This study will measure carbon, oxygen, and strontium isotopes from bulk tooth enamel bioapatite of mule deer. These three isotopes have proved extraordinarily useful in studies seeking to differentiate harvest events. Carbon isotopes help track variations in the diet and local vegetations consumed by individuals and vary with photosynthetic pathways, termed C_3 and C_4 pathways, first recognized as useful to ecological studies by Bender (1968) and further refined later on (O'Leary 1988; Tieszen 1994). Trees, herbs, and cool climate grasses use C_3 photosynthesis, which has $\delta^{13}C$ values in the range of -20 to -35‰ and a mean of -27‰ ± 3‰ and represent about 90% of plants from cold and temperate climates, including trees and herbaceous plans. It is understood that C_3 plants likely evolved earlier than C_4 during times of lower atmospheric CO_2 concentrations (Cannon 2008). Grasses in warm and dry climates, in addition to warm weather and tropical plants such as maize, sugar cane, and millet, use C_4 photosynthesis and have $\delta^{13}C$ values in the range of -7 to -16‰ with a mean of -13‰ ± 2‰ (Ehleringer 1989). These plants are more competitive than C_3 plants under stressful conditions such as temporary high light, intensity, and moisture stress (Cannon 2008). Though the main goal of this study's isotopic analysis is to examine the variability of carbon values as a proxy for mortality, carbon isotope signatures can serve as an indicator of paleoclimate. The use of carbon as a climate indicator stems from studies showing seasonal variation in C_3 and C_4 predominance (Tieszen 1994) and a correlation between C_4 grass species abundance and minimum growing season temperature (Terri and Stowe 1976). For example, relative and absolute C4 grass abundance correlates with mean annual temperature and mean annual precipitation on the Plains, while C_3 grasses decrease with mean annual temperature and precipitation. In sum, C_3 grasses thrive in spring and early summer when temperatures are cool and follow ample winter moisture. C_4 grasses, on the other hand, thrive following warm summers with summer precipitation.

In the past two centuries, the anthropogenic addition of CO_2 to the atmosphere from fossil fuel burning has depleted the levels of atmospheric CO_2 of $\delta^{13}C$. Prior to the introduction of anthropogenic CO_2, $\delta^{13}C$ values measured from Antarctic ice cores were measured at around -6.45‰, compared to modern estimates of around -8.0‰ (Cannon 2008). A conservative adjustment of about 1.5‰ must then be made to Holocene samples dating before 1800 A.D. in comparison to modern carbon values (Tieszen 1994: 264). Carbon isotope values prove useful in the recreation of plant ecology in the paleoenvironmental context of the site, lending insight into ancient cervid diets and how human foragers chose their prey. In this study, if the carbon isotopic values exhibit significant variability among mule deer at 48PA551, then it can be assumed that the individuals did not consume a similar diet and the remains are most likely the result of multiple harvests aggregated over time.

On the other hand, oxygen isotopes, track local climatic conditions, and tooth enamel bioapatite values correlate with the $\delta^{18}O$ of ingested water from drinking and dietary sources (Siegenthaler and Oeschger 1980; Hoppe 2004). The $\delta^{18}O$ values will vary with mean temperatures leading to low values in colder regions and higher values in warmer regions (Fricke and O'Neil 1996; Schoeninger et al. 2000; Hoppe 2004). Geographic differences in $\delta 18O$ values are quite pronounced in mountainous areas given that climatic conditions vary sharply with altitude (Siegenthaler and Oeschger 1980; Hoppe 2004). With the ingestion of meteoric water from surface water or vegetation, the oxygen isotopic composition is reflected in the tooth enamel bioapatite (Cannon 2008). Therefore, paleoclimatic changes can be understood with oxygen isotopes in addition to information about seasonal migrations, based upon where water was ingested. For example, water ingested from wetlands and lakes experiencing evaporation will have a much more isotopically enriched signature than ingested water from rivers and streams filled by seasonal snow melt, which should be isotopically depleted. This phenomenon is useful in this study given that related mule deer individuals will most likely have similar $\delta^{18}O$ values if they are part of the same herd. Higher variability in these values will show that specimens came from different parts of the landscape and are most likely not related.

The final isotope to be analyzed from tooth enamel bioapatite is strontium. Strontium is an isotope that is informative of the geographic region from which an animal's food and drinking water are derived during the time when tooth enamel was forming. The strontium isotopes track geographic changes in food and water because they are derived from local soils from bedrock weathering and atmospheric deposition. The isotopes of strontium also do not undergo any sort of biological fractionation, meaning the ratios of $^{86}Sr/^{87}Sr$ in the bedrock and soil will be equal to the ratio of ingested strontium by plant foods and water, represented in parts per million (Bentley et al. 2002, Price et al. 1994, 2002). Therefore, strontium isotope ratios reflect the geographic region from which the mule deer's food and water were derived during the time of enamel formation. Strontium isotope composition of plants, soils, and surface water on the landscape vary geographically due to the differences in age of bedrock composition.

Strontium isotope ratios have become an increasingly recognized tool useful for geolocation applied to archaeology, ecology, and forensic research. In order to geolocate specific samples, a solid understanding of variations in strontium ratios must be understood. This has led to the creation of isoscapes, which are continuous-probability surface models used in geographic assignment (Bataille et al. 2018). In this study, an isoscape of strontium ratios developed by

Bataille and Bowen (2012) is used to track the provenance of the $^{86}Sr/^{87}Sr$ mule deer enamel results. The isoscape in Bataille and Bowen (2012) was created using a GIS-based model for Sr isotopes in bedrock and water, including the combined effects of lithology and time, to create continuous raster datasets of $^{86}Sr/^{87}Sr$ values. Their effort represents one of the first attempts to create a strontium isoscape across the entire contiguous USA to be used as a provenance tracer, something that was previously not available for scientific study. While the authors demonstrated the isoscape model at times to be imperfect, it still provides a robust baseline for provenance studies at regional scales.

As with the previous two isotopes, this study will use strontium isotopic values to evaluate the relatedness of mule deer individuals with more variable strontium values indicating less related individuals and less variable values, meaning more related individuals. Since strontium values are tied to geographic locations of bedrock, then we would expect related mule deer individuals to occupy the same geographic areas, therefore, having very similar ratios of ingested strontium.

Stable Isotope Analysis and Harvest Scenarios

The previous discussion demonstrates how stable isotope analysis can provide a wealth of information concerning environmental conditions of prehistoric occupations at 48PA551. Beyond the use of isotopes as a paleoclimate indicator, Hoppe (2004) and Widga (2004) were some of the first to introduce isotopic ratio analysis as a way to investigate harvest scenarios. Hoppe (2004) used isotopic ratio variability in carbon, oxygen, and strontium isotopes to assess mortality events from two paleontological mammoth bonebeds and compared them to three Paleoindian archaeological mammoth assemblages. The expectation was that using isotopes as a biogeochemical signature helps identify related individuals only if the signature is less variable within an individual and family group than it is among unrelated individuals (Hoppe 2004: 138). This study found that in this case, oxygen and strontium isotopes were not useful in identifying related individuals, despite initial assumptions. Both isotope signatures displayed a much wider range of inter-individual variability than expected and could not distinguish between mammoth herds. However, carbon isotopic values reflected relative uniformity within and among individuals indicating a similar, unvaried diet (in the paleontological assemblage). Therefore, it was surmised that highly variable carbon values within an archaeological faunal assemblage indicate an accumulation of individuals harvested over time.

Widga (2004) used this same logic using carbon isotopic ratios among Archaic bison remains. They assumed that animals from the same herd would share similar carbon isotopes in bone collagen if they share similar foraging histories. This phenomenon is identified in confirmed multi-animal kill events in the Agate Basin and Hell Gap components of the Agate Basin archaeological site in Wyoming (Hill 2001). Widga (2004) argues that basecamps, where faunal remains are transported from multiple kills from different herds, can appear very archaeologically similar to a single herd, multiple-individual harvest. However, the isotopic signature should be very different in each scenario.

Fenner (2008, 2009) follows the approaches of these studies when addressing attritional versus mass kills of individuals in archaeological animal bonebeds, specifically focusing on pronghorn in Wyoming. Those studies used three different datasets to approach these questions, using both modern and archaeological pronghorn remains. The first two datasets were from teeth collected from harvested pronghorns during hunting season, organized by hunting districts across Wyoming. Secondly, a modern mass pronghorn die-off was used, resulting from the deaths of 150 pronghorn by falling from a cliff near Reiser Canyon, Wyoming, in 1991 (Lubinski and

O'Brien 2001). Finally, pronghorn samples from six archaeological sites in Wyoming were used to compare modern samples to archaeological samples. These sites included Austin Wash (Eckles 1999), Boars Tusk (Fisher and Frison 2000), Eden-Farson (Lubinski 1997), Firehole Basin (Middleton et al. 2007), Gailiun (Miller et al. 1999), and Trappers Point (Schroedl 1985) archaeological sites. Using carbon, oxygen, and strontium isotopes, the author statistically analyzed the ratios using basic descriptive techniques and scaled distance analysis that allowed for cross-comparison of all isotopes. The author found that the three-element isotope ratio distance measures successfully determined whether assemblages resulted from a single kill or catastrophic kill event, using known modern populations as control. Ultimately, this technique along with faunal analysis to determine population dynamics and other traditional methods, proved quite successful in addressing questions of harvest scenarios.

Mule Deer

Mule deer are common to the GYE and are found throughout Wyoming, Montana, and Idaho and are found in variable landscapes and habitats. Typically, mule deer occupy sagebrush and other browse-filled basins during winter and migrate to higher elevations during the summers to target tall-forb environments. However, the species is found across many landscapes, including pinyon-juniper forests, pine, and mixed-conifer forests, mixed-mountain shrubs, montane meadows, and high alpine areas (Kauffman et al. 2018). In general, mule deer are "concentrate selectors," requiring forage rich in nutrients and easily digestible. Therefore, they target emergent grasses and forbs in the spring and forbs throughout the summer. In winter, mule deer are browsers and heavily rely on woody shrubs such as mountain mahogany, bitterbrush, sagebrush, rabbitbrush, willow, and occasional berry bushes if present (Kauffman et al. 2018). Given the reliance on emergent grasses and forbs in the spring and summer that supply most of their nutrients for the year, mule deer migrate as far as 150 miles each spring and fall as they follow the "Green Wave" (Aikens et al. 2017). These creatures exhibit high fidelity to their migration routes and seasonal ranges, moving to and from different geographic areas with related individuals, following green-up, and avoiding inclement weather (Kauffman et al. 2018). In fact, mule deer GPS data from collared individuals from 2019 show documented migration routes directly through site 48PA551, including apparent stopover events, as they move from summer to winter range (Kauffman et al. 2020). Modern mule deer studies in recent years have focused on the human effects on populations, specifically related to impacts from climate change and development on migration corridors. These animal migrations are mostly understood from data gathered in the past few decades. Archaeological remains of ungulates can provide a crucial dataset to increase the time scale used to address these issues. Isotopic data like that in this study can provide wildlife managers with thousands of years of migration and ecology data to provide historical context for these at-risk species.

Given the discussion and importance of population dynamics of mule deer to understand harvest events, age distributions and sex ratios of herds must be understood. 48PA551 has ample evidence for being occupied and utilized during the winter. A late fall or early winter herd of mule deer would likely have fewer male than female deer in any given area. Breeding herds will have a male to female ratio of approximately 1:4 (Mohler et al. 1951; Simpson 1984). The age distribution in a herd such as this would have a living population made up of many young juveniles, followed by adult mule deer. The smallest proportion of a herd is made up of older adults (Nimmo 1971).

Mule deer are found in the archaeological record as early back as the Folsom period and remain present until the historic period (Kornfeld et al. 2010). 48PA551 represents one of the most notable sites with mule deer remains, not only from a large number of remains but as a result of an arrangement of cairns and male skullcaps with trophy-sized antlers, representing a meat cache or potential ceremonial feature (Frison and Walker 1984). The recent excavations at the site in 2018 located a small but dense mule deer bone bed along the cutbank (Thurman 2021), therefore becoming one of three known sites in the region with deer bone beds, along with the Helen Lookingbill site in the southern Absaroka Mountains (Kornfeld et al. 2001) and the Barton Gulch site in the Ruby Valley of southwest Montana (Davis et al. 1988). Deer remains also frequent many other sites in the region, though other sites did not note substantial bone beds like the others discussed above. Table 6.1 list sites within the region of study that recovered mule deer remains during excavation.

Table 6.1. Sites within and near the GYE contain archaeological deer remains.

Site Name	**Citation**
False Cougar Cave	Bonnichsen et al. 1986
Sorenson Site	Husted 1969
Mangus Site	Husted 1969
Mummy Cave	Husted and Edgar 2002
Pagoda Creek	Eakin 1993
Helen-Lookingbill	Kornfeld et al. 2001
Myers Hindman	Lahren 1976
Medicine Lodge Creek	Walker 1975
Prospects Shelter	Chomko and Gilbert 1987
Eagle Shelter	Chomko and Gilbert 1987

Big Lip Resevoir	Graham et al. 1987
Spring Creek Cave	Frison 1966
Leigh Cave	Frison and Huseas 1968
Wedding of the Waters Cave	Frsion 1962
Schiffer Cave	Frison 1973
Birdshead Cave	Bliss 1950
48PA551	Frison and Walker 1984

The deer assemblage at 48PA551 from the original excavations included approximately 50 individual animals. All remains most likely date solidly within the Middle Archaic given the dated strata and associated features. The skull and related elements such as mandibles had a much higher representation than other elements. Most limb elements (minus distal ends of humerus and tibia, and the astragalus) and vertebrae (except for cervical) were also poorly represented (Frison and Walker 1984). The population dynamics indicated that individuals were harvested between late October and March and that the ratio of males to females reflected a breeding herd (1:4). Interestingly, the age structure points to a catastrophic kill scenario instead of attritional harvest events, though it was suspected that the mortality events were temporally attritional (Simpson 1984). Overall, the interpretation of the mule deer remains were that a series of catastrophic harvest events occurred over an extended period of time.

The more recent investigations produced a much smaller sample size but still provided some insight and added to the known faunal assemblage, reinforcing the original findings. The 2018 excavations located an apparent bone bed along the cutbank of the adjacent creek containing over 5,700 individual specimens of mostly cervid and other mammals and approached a meter in depth. The initial analysis indicated that this area was likely a disposal area, due to the fragmentary nature of the remains, the relationship between axial and appendicular elements, and apparent differential treatment of axial and appendicular elements in butchering (Thurman 2021). This apparent activity area suggests a significant investment in butchering and processing for marrow, which supports that deer were taken during the winter.

Helen Lookingbill remains the earliest dated site with a deer bone bed dating to the Early Archaic (between 6460 and 9140 cal B.P.). The midden at the site was approximately 15 cm thick and contained over 2,497 individual specimens that included deer and sheep. Whole carcasses were represented, indicating local harvesting and butchering, and were disarticulated in a manner to make transport of high utility elements easier. From the faunal remains, the interpretation is that the site was a hunting camp occupied during the summer to fall where a small number of individuals were harvested. However, other characteristics suggest that the site may have been used as a residential camp when the lithic assemblage is taken into account. While deer were obviously targeted at this site, the prey choice does not seem to be as specialized as that of 48PA551, which may reflect the differences in population density of mule deer in the respective areas (Kornfeld et al. 2001, 2010).

The Barton Gulch site also contains a small mule deer assemblage but is far less extensive than 48PA551 or even Helen Lookingbill. Only an MNI of two mule deer was recovered from excavations at the site in southwest Montana. However, the deer remains were heavily processed, given extensive cutmarks and impact fractures on bones. Evidence of contact with high heat is also present on the remains, suggesting cooking or roasting activities (Davis et al. 1988; Kornfeld et al. 2010). The site is one of only a handful that reflects deer harvesting and heavy processing during the mid-Paleoindian times (Walker and Driskell 2007).

Mule deer are an ideal species to use in stable isotope analysis, given their migratory behavior and strict adherence to specific migration corridors and winter/summer ranges. As the discussion above suggests, the information from stable isotopes can provide incredible context for archaeological sites. Paleoenvironmental records, logistical organization of hunter-gatherers, harvest events, and more can all be addressed with the analysis results. This often-overlooked species in the archaeological records of the northwestern Plains and the Rocky Mountains deserves more attention given the wealth of information the remains can provide. While this study focuses on harvest scenarios, isotopic data can provide important ecological and paleoclimate data and is discussed below.

Methods

Isotopic analysis was performed on ten mule deer teeth samples by the University of Georgia Center for Applied Isotope Studies (CAIS). The third molar (M3) was removed from the left side of mule deer mandibles and analyzed, given that the M3 forms during adulthood. This means that the isotopic signatures will reflect the actual diet, ingested water, and geographic occupation of the individual. Other molars likely may have remanant isotopic signatures from the individuals' mothers, acquired through milk while nursing. Tooth enamel was used instead of bone collagen to avoid issues with diagenesis, where bone chemically turns over and isotopically changes periodically throughout the life of the organism. Additionally, tooth enamel bioapatite is a better reflector of diet given that bone collagen isotopes only reflect the signatures of ingested protein. The following methodology was provided by Dr. Carla Hadden, Assistant Research Scientist at the University of Georgia. For the analysis of oxygen and carbon isotopes, subsamples of tooth enamel were pretreated with acetic acid following Cherkinsky (2009) to remove secondary or diagenetic carbonates. The samples are then reacted in 1N acetic acid overnight. The flasks containing the samples are then evacuated and re-pressurized periodically, and when the reactions cease, the samples are rinsed voluminously in ultrapure water and dried at 60 degrees C. Approximately 1 mg of each pretreated bioapatite sample is then reacted with 100% phosphoric acid in flushed exetainer vials to produce CO2, and stable isotope ratios (δ13C and δ18O) are measured using a Thermo GasBench II-IRMS. Internal standards designated A1296 and Fisher are analyzed along with the unknowns. Values will be expressed as δ13C and δ18O with respect to VPDB, with an error of less than 0.1‰.

Strontium isotopes are analyzed in a different manner than carbon and oxygen isotopes and are outlined by Dudas et al (2016). Tooth enamel was mechanically separated from the teeth, then gently crushed to small fragments. The material was then treated to remove diagenetic strontium following the procedure outlined in Dudas et al. (2016). Following these pretreatment procedures, the remaining material was then dissolved in ultrapure HNO3 and strontium was separated by standard ion-exchange procedures using Sr-Spec resin from Eichrom. Strontium isotopic compositions are determined at the University of Georgia CAIS on a Nu-Plasma II MC-ICP-MS in static mode. 87Sr/86Sr ratios are corrected for mass bias using exponential law and 86Sr/88Sr=0.1194. 87SR is corrected for the presence of Rb by monitoring the intensity of 85Rb and subtracting the intensity of 87Rb from the intensity of 87SR using 87Rb/85Rb = 0.386 and a mass bias correction factor determined from 86Sr/88SR. All analyses are corrected for isobaric interference of Kr impurities in the Ar gas by using on-peak measured zeros determined on an ultra-high purity 2% HNO3.

Basic descriptive statistics such as the mean and standard deviations for each isotope were calculated to quickly assess the variability across the sampled molars. Standard deviation is used as a basic indicator for potentially related individuals and identifies the variability between specimens for each isotope. However, the raw standard deviations are not directly comparable between different isotopes. Different isotope ratios are expected to vary by group, and the magnitudes and/or ranges of the three isotopes discussed here differ substantially. Therefore, this study followed the statistical protocols outlined in Fenner (2008) and scaled each isotope so that they could be compared together. Isotope values are scaled to match the oxygen values, given it has the largest raw scale, and are scaled about the origin. The values are scaled using the following equations taken from Fenner (2008):

$$\delta^{13}\mathrm{C}_\mathrm{s} = (\delta^{13}\mathrm{C}_\mathrm{m} - \overline{C_\mathrm{g}})\,\frac{R_\mathrm{O}}{R_C}$$

$$\delta^{18}\mathrm{O}_\mathrm{s} = \delta^{18}\mathrm{O}_\mathrm{m} - \overline{O_g}$$

$$\mathrm{Sr}_s = (\mathrm{Sr}_\mathrm{m} - \overline{\mathrm{Sr}_g})\,\frac{R_\mathrm{O}}{R_\mathrm{Sr}}$$

The "s" subscript is the resulting scaled value for the listed isotope, while the "m" represents the raw isotopic value for each specimen. The "g" subscript identifies the mean isotopic value for each element, and "R" represents the overall range for each element. Continuing with the Fenner (2008) protocol, these standardized values are combined into a three-dimensional Euclidean distance analysis to assess the variability of all isotope ratios between specimens within the site. This equation taken from Fenner (2008) is also identified below:

$$D_i = ([\delta^{13}C_s(i)]^2 + [\delta^{18}O_s(i)]^2 + [Sr_s(i)]^2)^{0.5}$$

D_i represents the three-dimensional Euclidean distance from one individual deer specimen to all others in the analysis. The resulting Euclidean distance calculation values are plotted in three dimensions to spatially show the relationships between individual deer specimens. The mean and standard deviation of the distance measures is calculated to assess overall variability in the dataset.

Hypotheses

Returning to the main hypotheses discussed at the beginning of this dissertation, we can articulate how the results of this chapter can be used to interpret one of the scenarios. To summarize, the overarching hypotheses generally seek to determine whether 48PA551 was a communal hunting ground occupied by individuals from different socio-political groups or bands or was a hunting ground tied to a specific groups' territory. One of the test expectations of those hypotheses relies on understanding the harvest events of specifically mule deer. Therefore, this chapter has two dichotomous sub-hypotheses that address this test expectation.

The first sub-hypothesis suggests that this was a communal hunting ground that would be supported by a catastrophic or mass-kill event. Isotopically, this would mean that there should be relatively little variability in the isotopic ratios between individual mule deer specimens. Oxygen values should indicate that the deer experienced the same temperature conditions and drank from the same water sources, and be within a single standard deviation from one another. Carbon values, also tied to climate, should indicate a similar diet of C3 or C4 grasses and fall within one standard deviation of one another. Bulk strontium isotope ratios should reflect a similar geographic range of individuals, as determined by the strontium values in bedrock geology, ingested by deer through browse and water. The Euclidean distance of scaled values should all cluster together and be within one standard deviation of one another.

The second sub-hypothesis supports the idea that communal hunting did not occur and that this area was used as a winter hunting camp controlled by a single group over an extended period of time. The harvest scenario under this condition would likely be an attritional harvest over time. Isotopically, this would be reflected by a high degree of variability in the mule deer samples. Oxygen values will be highly variable, beyond a single standard deviation reflecting different climatic and temperature conditions. Carbon values will be highly variable, beyond one standard deviation from one another, indicating different diets. Strontium values will also be beyond a single standard deviation, indicating that the deer migrated through different geographic regions and, therefore, areas with different bedrock signatures. The scaled Euclidean distance analysis should have highly variable distance values and most samples will be beyond a single standard deviation from one another.

Results

Raw isotope values are still important on their own despite the lack of being able to compare one element to another without scaling directly. As a reminder, strontium ratios are a product of bedrock range, indicating the average ingested strontium value of a mule deer's range. The higher the strontium ratio, the older the bedrock. In this part of the country, the weathered basins and river valleys house the oldest sedimentary bedrock, while the younger bedrock occurs in the uplifted mountains and volcanic ranges. Figure 6.1 shows the contrast in strontium value and age, highlighted by the younger Absaroka Range (in dark green) contrasting with the old sediments and bedrock of the Bighorn Basin (in red, yellow). The strontium bedrock isoscape is a model developed by Bataille and Bowen (2012) discussed earlier in this chapter. The strontium samples have an average value of 0.7088 (sd = 0.002) and have a range of 0.006.

The range of values in Table 2 reflect substantial range in bedrock age. Figure 6.2 displays a series of maps identifying the bedrock strontium values in this region of study, indicating the potential ranges of each of the samples. Three samples had an average strontium ratio that corresponds to the Absaroka Mountain range, all falling between a value of 0.706 and 0.707 (samples, UW-I-020, UW-I-022, and UW-I-023). Two samples fall in the strontium range of 0.707 and 0.708 (UM-I-002 and UW-I-011), which spatially fall on the edges of the youngest mountain ranges. Two more samples fall between strontium values 0.708 and 0.709, which are found in areas with slightly older bedrock found in the western portion of Yellowstone National Park and the Bighorn Basin. No samples averaged strontium ratios were between 0.709 and 0.712. However, the final three samples averaged values consistent with some of the oldest bedrock with values between 0.712 and 0.713. These areas fall within the basins and in areas where mountain ranges uplifted old, sedimentary bedrock.

The raw carbon values vary between -10.61 to -6.36‰, with a range of 4.21‰. The average value is -9.39‰ with a standard deviation of approximately 1.24‰. These carbon values fall right in the range of C_4 grasses, which usually range around -13‰ ± 2‰ and are indicative of warm and dry climates. C_4 grasses may also indicate grasses ingested at lower elevations as opposed to C_3 vegetation at higher elevations that generally experience cooler and moister conditions given the altitude. Given the wintertime occupation and harvest of mule deer at 48PA551, the deer were likely at lower elevations in winter range given the normally deep snowpack at higher elevations.

Table 6.2. Raw isotope values.

Sample	**$^{87}Sr/^{86}Sr$**	**$\delta^{13}C$ (‰VPDB)***	**$\delta^{18}O$ (‰VPDB)**
UM-I-001	0.712989	-9.40	-7.22
UM-I-002	0.707667	-6.36	-15.99
UW-I-011	0.707303	-10.09	-9.23
UW-I-012	0.708320	-8.89	-9.86
UW-I-016	0.708713	-10.57	-8.89
UW-I-018	0.712000	-8.35	-12.64
UW-I-020	0.706739	-9.62	-8.53
UW-I-022	0.706767	-10.61	-7.53
UW-I-023	0.706830	-10.54	-7.45
UW-I-024	0.711052	-9.51	-9.65
Mean	0.708838	-9.39	-9.70
Std. Dev.	0.002211	1.2352153	2.577034
Range	0.006251	4.21	8.77
*added 1.51‰ to account for modern fossil fuel burning			

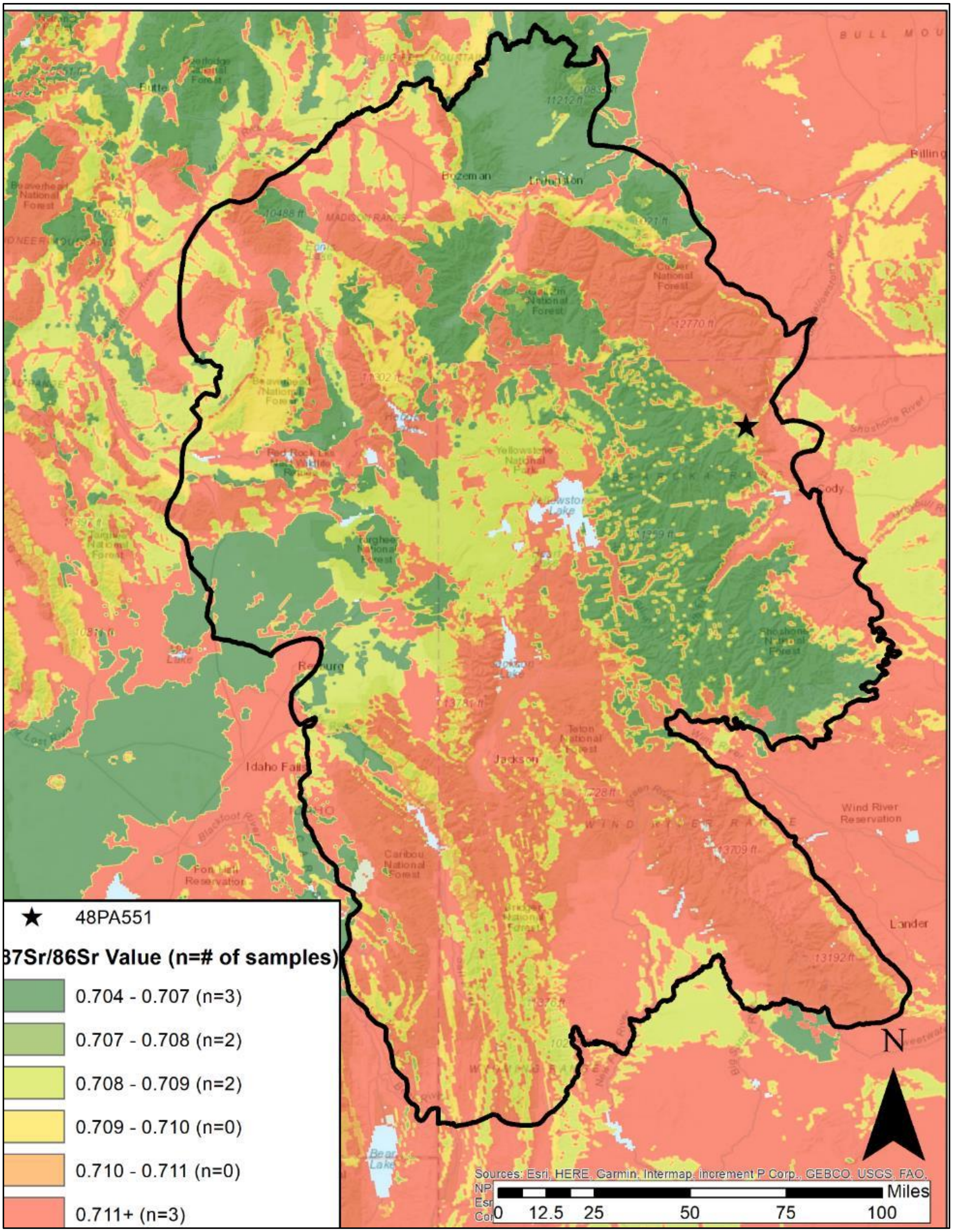


Figure 6.1. Isoscape map indicating strontium values derived from Bataille and Bowen (2012).

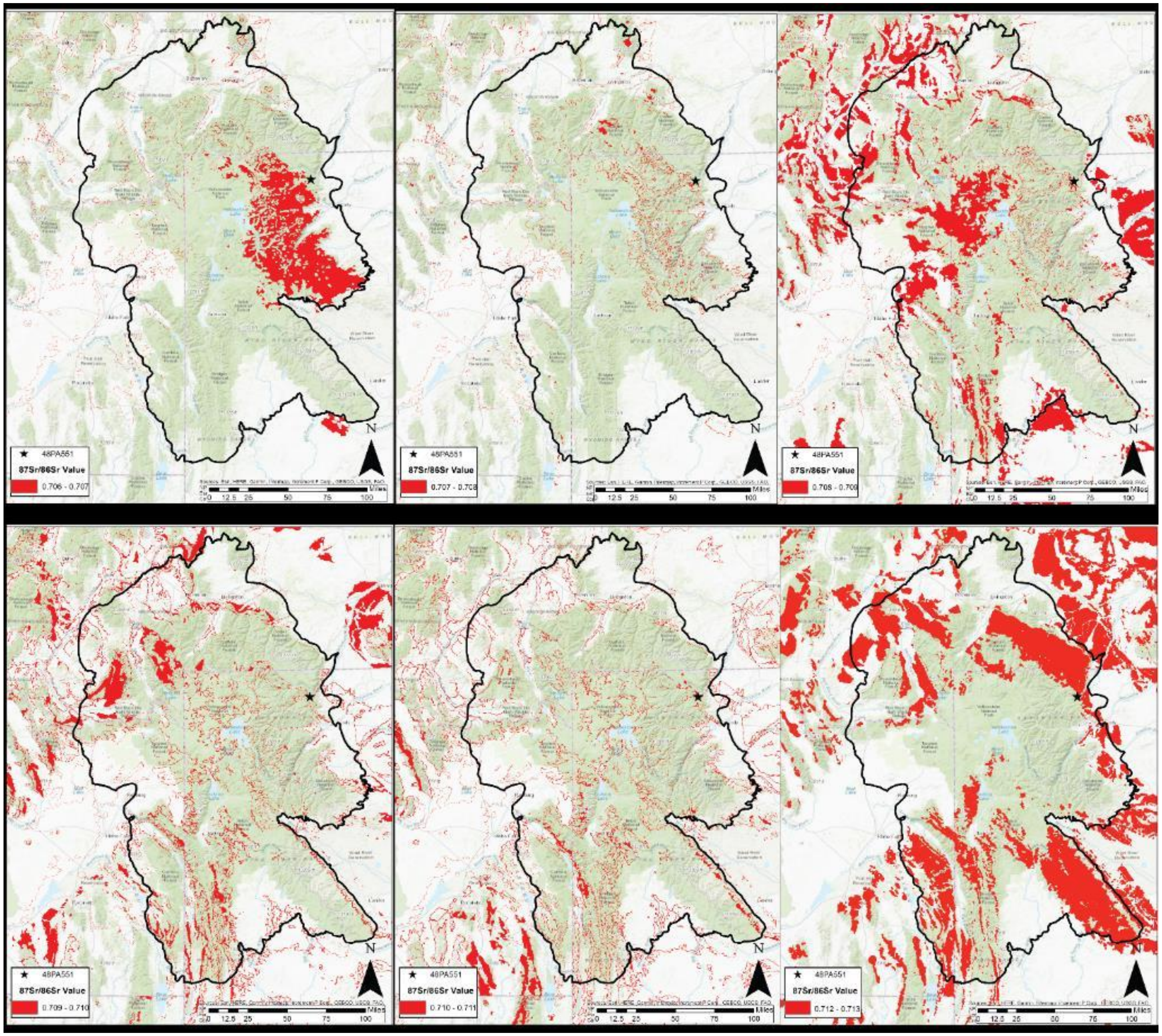


Figure 6.2. Distribution of strontium values in region by 0.001 intervals.

The raw oxygen isotopic values of the sample reflect an environment and season of isotopically enriched water sources. The values have the largest range of all isotopes, which is expected with oxygen, with a range value of 8.77. The values range from -7.22‰ to -15.99‰, where the upper end falls as somewhat of an outlier. The mean value of oxygen isotopes is -9.7‰ with a standard deviation of 2.58. While streams and high elevation lakes filled by snowmelt runoff have isotopically depleted values, lower elevation lakes, wetlands, and streams have enriched values due to higher evaporation levels. Most oxygen values in this sample indicate ingested water from water sources not fed by seasonal runoff, indicating potentially lower elevation water sources during winter, where runoff is not yet occurring. These implications further support original interpretations of wintertime mortality.

As stated above, isotopic values were standardized and scaled to compare all element values together. The scaled values are listed in Table 3, which center values about the origin. These values were then used as X, Y, Z coordinates in a three-dimensional Euclidean distance calculation, where coordinates were strontium, carbon, and oxygen scaled values, respectively. Table 4 represents the three-dimensional Euclidean distance matrix with the values between all samples. The mean distance between points is 6.72308, with a large standard deviation of 4.70106. Many of the values are quite far apart in the matrix, with double-digit distances between points. However, the highlighted values in Table 4 indicate the distances between points within a single standard deviation, suggesting that the high mean distance may not adequately describe data. Furthermore, samples UW-I-022 and UW-I-023 fall in almost identical locations of the Euclidean matrix, raising the possibility that certain subsets of samples may cluster together.

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Table 6.3. Scaled isotope values.

Sample	$^{87}Sr/^{86}Sr$	$\delta^{13}C$	$\delta^{18}O$
UM-I-001	-0.024	2.481	5.825
UM-I-002	6.312	-16.697	-1.642
UW-I-011	-1.449	-9.235	-2.154
UW-I-012	1.041	-9.856	-0.727
UW-I-016	-2.453	-8.894	-0.176
UW-I-018	2.167	-12.644	4.437
UW-I-020	-0.486	-8.533	-2.946
UW-I-022	-2.544	-7.527	-2.906
UW-I-023	-2.387	-7.448	-2.818
UW-I-024	-0.251	-9.649	3.107

Table 6.4. Three-dimensional Euclidean distance matrix. Highlighted values show values within one S.D. of each other. Thick border boxes show almost identical values.

Sample	**UM-I-001**	**UM-I-002**	**UW-I-011**	**UW-I-012**	**UW-I-016**	**UW-I-018**	**UW-I-020**	**UW-I-022**	**UW-I-023**	**UW-I-024**
UM-I-001	0	10.247	14.2415	14.0086	13.0874	15.3448	14.0865	13.5174	13.3735	12.4319
UM-I-002	10.247	0	10.782	8.68447	11.8263	8.40012	10.7035	12.8108	12.7515	10.7378
UW-I-011	14.2415	10.782	0	2.9374	2.24352	8.25664	1.42844	2.1598	2.12044	5.41192
UW-I-012	14.0086	8.68447	2.9374	0	3.66566	5.97559	3.001	4.79839	4.68209	4.05113
UW-I-016	13.0874	11.8263	2.24352	3.66566	0	7.52906	3.41648	3.05448	3.01255	4.02454
UW-I-018	15.3448	8.40012	8.25664	5.97559	7.52906	0	8.85706	10.1142	10.0186	4.07255
UW-I-020	14.0865	10.7035	1.42844	3.001	3.41648	8.85706	0	2.29107	2.19258	6.1595
UW-I-022	13.5174	12.8108	2.1598	4.79839	3.05448	10.1142	2.29107	0	0.19656	6.7762
UW-I-023	13.3735	12.7515	2.12044	4.68209	3.01255	10.0186	2.19258	0.19656	0	6.67177
UW-I-024	12.4319	10.7378	5.41192	4.05113	4.02454	4.07255	6.1595	6.7762	6.67177	0
Mean	*6.72308*									
Std Dev	*4.70106*									
Range	*15.14824*									

Discussion

At first glance, the variability in isotopic data appears to be significant enough to confidently conclude that the sampled deer remains are not part of the same population or herd and were therefore not harvested in a mass kill event. To put this in perspective, Fenner (2009) conducted the same analysis on archaeological pronghorn bone beds and determined that at three archaeological sites in their sample, the bonebeds were likely the result of a single population, (Boars Tusk, Eden-Farson, and Firehole Basin sites). In these cases, the Euclidean distance of the standardized and combined isotope measures was less than three (1.6, 2.94, and 2.69, respectively). In comparison, 48PA551 produced an average distance measure of 6.72 between specimens, far greater than those sites considered to be from a single population. Overall, the data supports multiple attritional harvest events over a period of time and is not reflective of a mass kill event of a single mule deer herd.

Although the sampled mule deer remains do not appear to be part of the same herd, there is more nuance to the data when you begin to consider other factors. First of all, the range of average distance between sampled specimens is quite large (15.14824), meaning that distances in the dataset are quite variable. Table 4 illustrates the closer distance measures by highlighting distances within a single standard deviation. If we go a step further and use the logic in Fenner (2009) and use a distance measure of less than or equal to three as a line of evidence for related populations, we see a number of interesting relationships. Table 5 highlights the relationships with a distance value of less than or equal to three and identifies 18 distance relationships below that threshold. While the idea is tentative given the sample size, these relationships may indicate that a subset of the mule deer sample is related.

Table 6.5. Three-dimensional Euclidean distance matrix highlighting distances less than or equal to 3.0.

Sample	**UM-I-001**	**UM-I-002**	**UW-I-011**	**UW-I-012**	**UW-I-016**	**UW-I-018**	**UW-I-020**	**UW-I-022**	**UW-I-023**	**UW-I-024**
UM-I-001	0	10.247	14.2415	14.0086	13.0874	15.3448	14.0865	13.5174	13.3735	12.4319
UM-I-002	10.247	0	10.782	8.68447	11.8263	8.40012	10.7035	12.8108	12.7515	10.7378
UW-I-011	14.2415	10.782	0	2.9374	2.24352	8.25664	1.42844	2.1598	2.12044	5.41192
UW-I-012	14.0086	8.68447	2.9374	0	3.66566	5.97559	3.001	4.79839	4.68209	4.05113
UW-I-016	13.0874	11.8263	2.24352	3.66566	0	7.52906	3.41648	3.05448	3.01255	4.02454
UW-I-018	15.3448	8.40012	8.25664	5.97559	7.52906	0	8.85706	10.1142	10.0186	4.07255
UW-I-020	14.0865	10.7035	1.42844	3.001	3.41648	8.85706	0	2.29107	2.19258	6.1595
UW-I-022	13.5174	12.8108	2.1598	4.79839	3.05448	10.1142	2.29107	0	0.19656	6.7762
UW-I-023	13.3735	12.7515	2.12044	4.68209	3.01255	10.0186	2.19258	0.19656	0	6.67177
UW-I-024	12.4319	10.7378	5.41192	4.05113	4.02454	4.07255	6.1595	6.7762	6.67177	0
Mean	*6.72308*									
Std Dev	*4.70106*									
Range	*15.14824*									

Similar to the lithic samples in the previous chapter, the exact spatial provenience for the original excavation samples is not well understood. However, enough information was present to tie samples to the general block locations identified in previous chapters. Vertical provenience was not available from enough samples to draw any meaningful conclusions. Figure 6.3 illustrates the horizontal distribution of sampled mule deer molars and labels the two largest original block excavations as "A" and "B." Table 6 illustrates the descriptive statistics in each area. In Area A, despite being horizontally related, the isotopic variation is still considerably high. For example, strontium values in this area have a large range indicating very different geographic locations. The ranges of carbon and oxygen values are also wide-ranging. The average Euclidean distance between these points is less than the overall mean from all samples but still results in an average distance of 5.28. Some of the samples in this area may have a relationship and have distances below the threshold of three. Samples UW-I-012 and UW-I-20 fall right at the distance threshold, but no other samples in Area A have a significant relationship.

Area B, on the other hand, reflects a much different relationship. Though only three samples were sourced from this area, the isotopic signatures are much more closely aligned. The strontium values all reflect younger bedrock parent material, likely from the Absaroka Mountains. Carbon values in Area B only have an overall range of 0.52, suggesting a similar diet. Oxygen values range the most where the value from UW-I-011 differs from the other two samples in the area. The small degree of variation between the raw values in this sample is reflected by a small average Euclidean distance between the three samples, equaling 1.49. Despite the small sample size from Area B, the evidence is compelling enough to safely say that there is a relationship between the samples and that they likely originated from the same herd.

Spatial relationships combined with limited degrees of variance in isotope ratios are a strong indicator of related individuals. Despite the small sample size in provenienced areas, there are likely real relationships we can see across the site. It appears that the isotope data reflect a series of harvest events, supporting the attritional kill scenario. However, it also seems likely that multiple individuals were harvested at a time given the spatially and isotopically clustering of certain individuals. While not reflecting a larger catastrophic event of an entire herd, it appears that small groups of deer were taken at a time, which likely was not accomplished by a single individual. In sum, cooperative, small-group hunting events may have occurred at 48PA551.

Table 6.6. Descriptive statistics of isotope values from Area A and Area B.

Area A Samples	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}_{\text{VPDB}}$*	$\delta^{18}\text{O}_{\text{VPDB}}$
UW-I-012	0.708320	-8.89	-9.86
UW-I-016	0.708713	-10.57	-8.89
UW-I-018	0.712000	-8.35	-12.64
UW-I-020	0.706739	-9.62	-8.53
UW-I-024	0.711052	-9.51	-9.65
Mean	0.709365	-9.39	-9.91
Std. Dev.	0.001908	0.75	1.45
Range	0.003680	2.22	4.11
Avg. Distance = 5.28			
Area B Samples	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}_{\text{VPDB}}$*	$\delta^{18}\text{O}_{\text{VPDB}}$
UW-I-011	0.707303	-10.09	-9.23
UW-I-022	0.706767	-10.61	-7.53
UW-I-023	0.706830	-10.54	-7.45
Mean	0.706967	-10.41	-8.07
Std. Dev.	0.000239	0.23	0.82
Range	0.000537	0.52	1.78
Avg. Distance = 1.49			

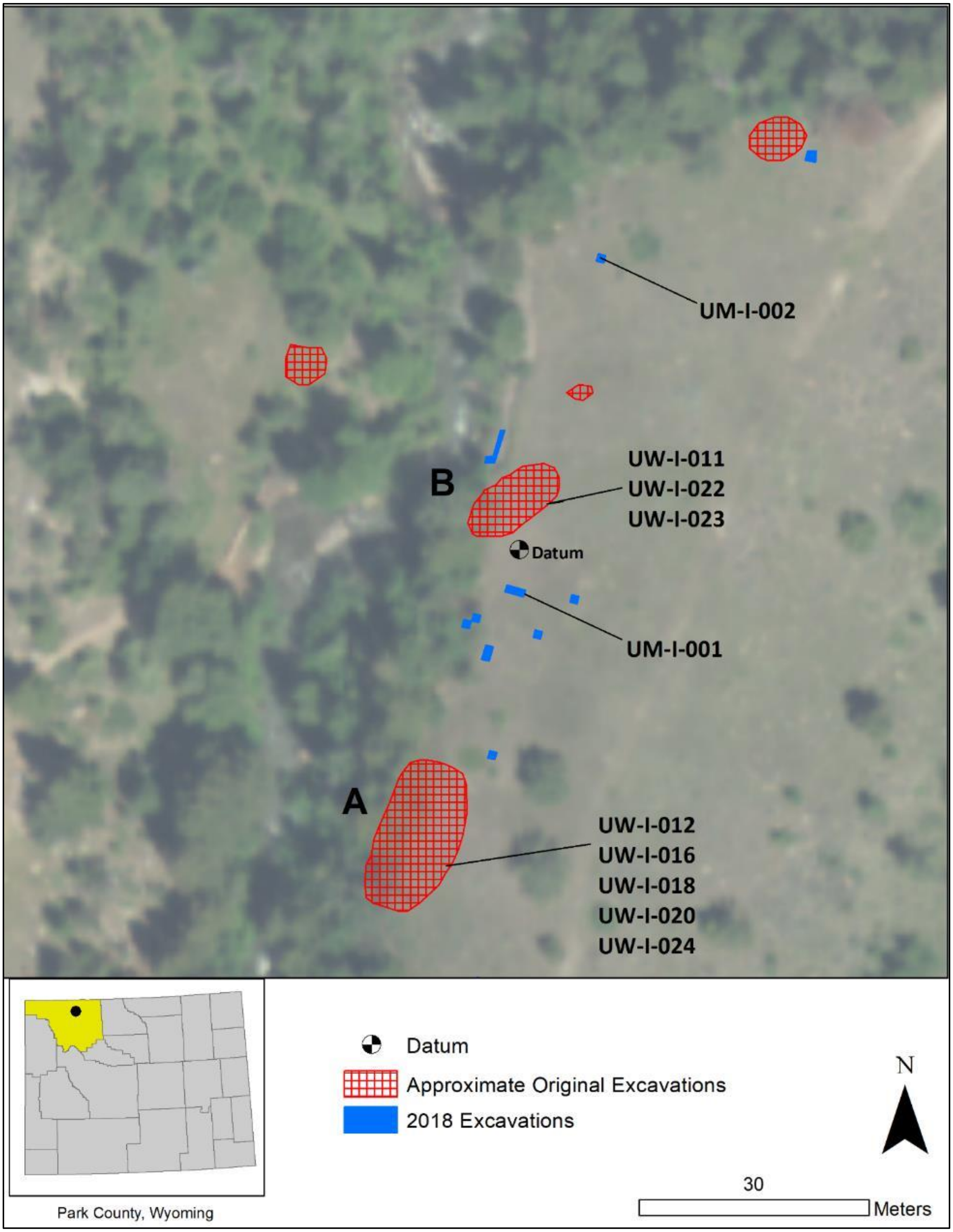

Figure 6.3. Distribution of isotope samples across the site.

While the hypotheses in this chapter focused on harvest event scenarios, the ecological implications of the dataset must be discussed, as they reflect important paleoenvironmental conditions from the Middle Holocene. Starting with the strontium data, the diverse set of values is a product of mule deer behavior. We can use the strontium values to track this behavior through time, given what we know about mule deer seasonal migration and the strict adherence to summer and winter ranges and migration corridors. As discussed previously, the strontium values reflect a varied geographic range of mule deer, from the young mountain ranges to the west and the older basins to the east. This east-west variation maps quite closely to the GPS collar data from different mule deer individuals in the Clarks Fork herd (Kauffman et al. 2020). Figure 6.4 illustrates the migration corridors of a series of mule deer during the spring and fall in relation to the strontium bedrock values. These routes pass through the whole range of observed strontium values in the sampled dataset, from the interior of Yellowstone National Park to the Bighorn Basin. Given the variability observed in the data, it is highly likely that the deer harvested near 48PA551 made a similar journey. Incredibly, the implication of the strontium variability means that these migration corridors have likely been intact since the Middle Holocene. The sustained routes and ranges solidify our modern understanding of mule deer and show that this behavior is not a recent adaptation. We are likely looking at an adaptation and migration corridors that are over 5,000 years old. It is important to keep in mind that the strontium values in this study were bulk samples, measuring the average strontium value in the molar. Seriation or down-tooth studies can provide further information about migration, providing a series of strontium snapshots as the tooth formed, but this sampling method was not used in this study.

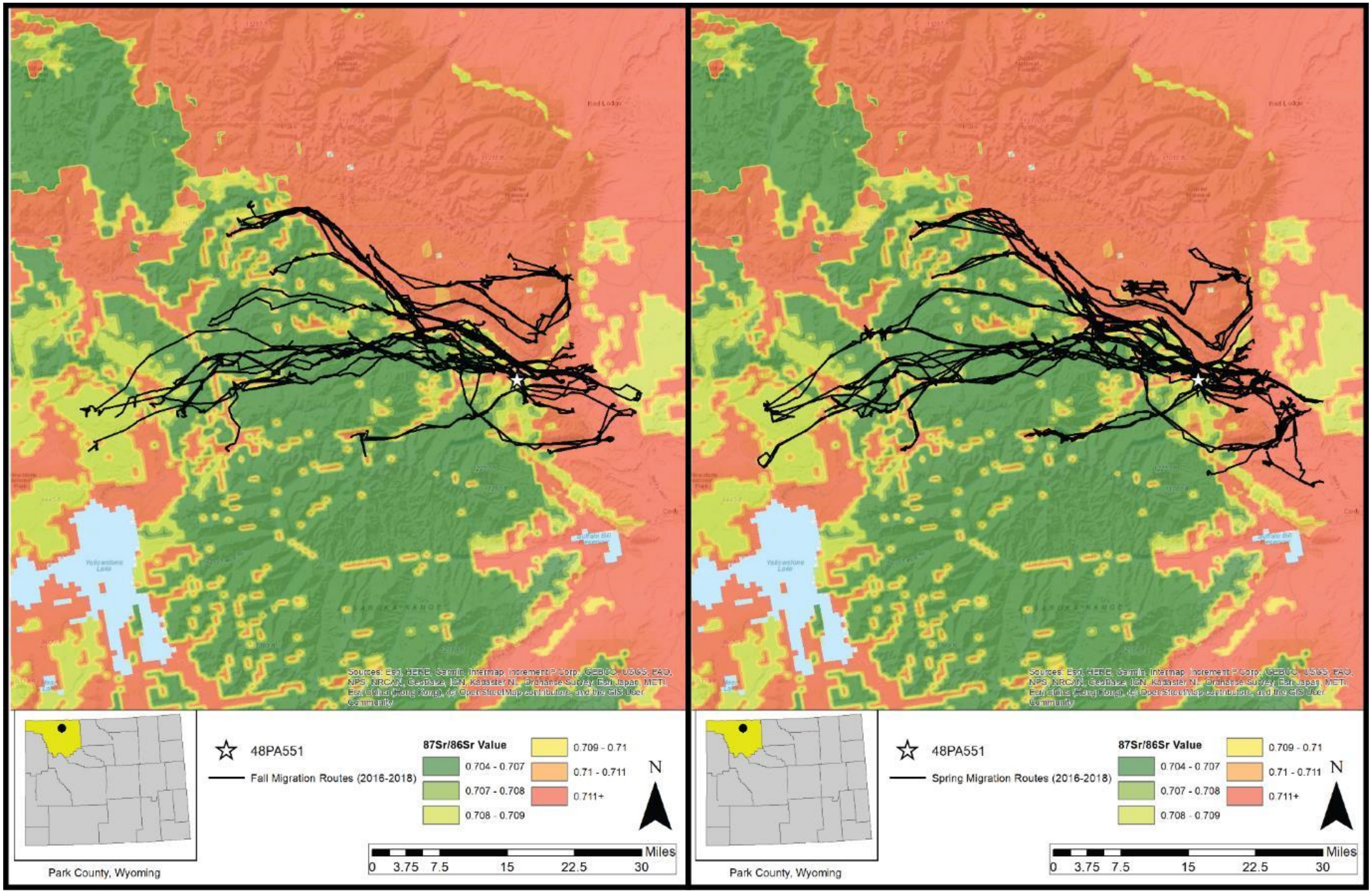

Figure 6.4. Fall vs Spring migration routes of the Clarks Fork herd (2016-2018). Note almost identical routes. Fall travel direction is west to east while spring is east to west.

Oxygen and carbon isotopes, as discussed above, can be used as related indicators of paleoclimate and even spatial or migratory indicators. For example, C_4 plants thrive when summers are hot and solar radiation is high, while C_3 plants increase when growing seasons are cool and cold (Bird et al. 1994; Ehleringer et al. 1991; Hughes 2003; Teeri and Stowe 1976). Additionally, if both C_3 and C_4 plants are present in the region, drought conditions will cause C_4 plants to increase in proportion to C_3. As discussed above, the carbon values extracted from the tooth enamel all squarely fit within the expected range of C_4 plants. The dominance of C_4 plants in the sample is interesting for several reasons. First, the implication of dominant C4 plants in the region means that summers were quite warm with intense solar radiation. This suggested climatic regime runs counter to the generally assumed, wider pattern of cooler and wetter conditions during the Middle Holocene (see discussion in Chapter 2). C_4 plants are quite abundant in the Bighorn Basin and Absaroka Mountain foothills to the east of the site, an ecosystem dominated by semi-arid conditions (Hughes 2003). If annual temperatures were warmer and drier, forested zones in the region would likely rise in elevation, and low elevations grasslands and plant communities from the basins would expand. Additionally, C_4 species would increase at lower elevations and outcompete C_3 species (Hughes 2003). Normally, deer species are generalized browsers and obtain most nutrients from C_3 species such as tree and shrub shoots and leaves. However, carbon values fell outside of the C_3 of this expected range, despite expectations that carbon ratios would not change through the Holocene no matter the climate given the generalized browse diet of mule deer (Hughes 2003).

The dominance of C_4 levels of carbon in the tooth enamel is compelling when considering the climatic implications. For example, Hughes (2003) sampled modern deer in the region which averaged a carbon value of -21.4‰, within the range of C_3 species. Hughes (2003) also sampled eight mule deer from eight different strata at Mummy Cave and produced a range of carbon values from -18.7 to -21.1‰, aligning with C_3 species no matter the period in time. Instead, the mule deer samples from this study reflect a much higher C_4 diet like that of a grazer, such as bighorn sheep. Modern mule deer from the interior of Yellowstone National Park sampled by Feranec (2004) reflect a closer carbon signature to that of the archaeological sample at 48PA551 and averaged -13.33‰ and a range from -9.42‰ to -15.1‰ (n=31). Instead, the isotopic signature of the archaeological samples is much more aligned to the isotope signatures in pronghorn or antelope. For example, the six archaeological sites with pronghorn remains used in Fenner (2009) contained samples with a range of average carbon values between -8.65‰ and -11.51‰. If climatic conditions supported an expansion of C_4 grasses and a retreat of timber lines, then the area near 48PA551 may have been home to an ecosystem with a plant community reflecting those of the nearby, lower-elevation semi-arid basins. On the other hand, it also may indicate that the hunting strategy at 48PA551 targeted arid, dry basins nearby 48PA551. In either scenario, the results prove to be divergent from the findings of other, similar studies such as those at Mummy Cave to the south, which are much farther from the xeric basins (Hughes 2003). Overall, given the average carbon value, the sampled deer were likely consuming a C_4 dominate diet, making up at least 75% of their diet (Hughes 2003).

Oxygen isotopes are known to demonstrate a correlation between the oxygen ratios of mammalian tooth enamel and the oxygen ratios of local surface waters and precipitation (Hoppe 2006). The wide range of oxygen values in samples from 48PA551 is likely the product of mule deer migration through a region with a number of different water sources. Hughes (2003) also identified this phenomenon in migratory species such as mule deer from Mummy Cave. Despite the large range, most of the mule deer oxygen values represent more oxygen-enriched water sources less influenced by seasonal snowmelt. The values may also be more enriched given that deer are water conservers and are not obligate drinkers. Instead, mule deer are a more drought-tolerant species that receives water through browse such as leaves, containing water enriched by almost 10‰ in arid climates over meteoric water (Forstel 1978; Zundel et al. 1978). The enriched values in these conditions reflect an environment that lacks moisture. Likely, the mule deer oxygen ratios originate from the arid, semi-desert basins close to the site, which support the carbon isotope results.

The relationship between carbon and oxygen can provide more evidence about the ecological conditions in which the deer lived. Despite some variability, each isotope reflects an arid and xeric environment in which mule deer ingested food and water. Overall, it indicates that the herds spent a significant amount of time on the eastern slopes of the Absaroka Mountains and dry basins such as the Bighorn Basin. Beyond just the habitat, the carbon values indicate that the majority of their diet was comprised of C_4 plant species, present more under drought conditions. Additionally, increased enrichment of oxygen values is expected in warmer and more arid conditions, especially when the browsing species like mule deer consume leaves. This means that even though they likely occupied drier areas, the overall climate was likely warm and dry. The direct comparison of raw carbon and oxygen values lends insight into whether the habitat of a species was more open or closed. More positive carbon values are found in open habitats such as grasslands and savannas, while more negative values are found in closed habitats such as woodlands and forests (Fenerac and MacFadden 2006). Generally, taxa inhabiting closed environments have relatively negative carbon and oxygen values. Figure 6.5 illustrates the relationship between carbon and oxygen mule deer specimens from 48PA551. Interestingly, they point to a more closed environment, though viewing isotope values separately point to the dry, normally open basins. However, evidence for deer occupying both environments may also be a product of migration, given that the species passes through a diverse landscape on their journey.

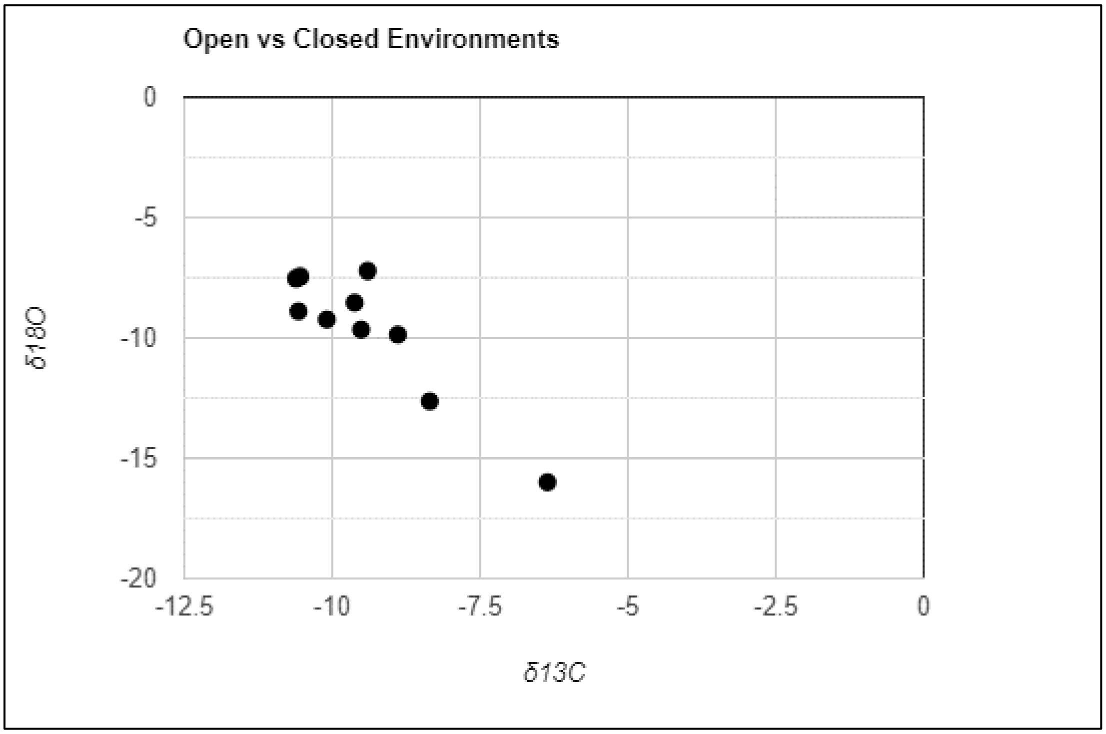

Figure 6.5. Relationship between carbon and oxygen values reflecting a more open environment.

Conclusions

The isotope data from the mule deer specimens at 48PA551 proved to be extraordinarily useful in assessing theoretical implications of hunting strategies and the recreation of paleoenvironmental conditions. The data overwhelmingly suggests that the sampled mule deer originated from different herds and were unrelated individuals. Therefore, they were not all harvested simultaneously, eliminating the possibility of a catastrophic or mass kill event. However, there appears to be a handful of related individuals within the dataset, which reflects a series of harvest events where multiple individuals were taken. Given the series of harvest events over time, the site was likely a reliable place to harvest mule deer during the winter. Small groups may have participated in a series of hunts, taking a few individuals from a herd at a time.

The observations of modern mule deer using this area as a migration corridor to winter range is a testament to the reliability of this resource for hunter-gatherers. The relationship between the archaeological data and modern GPS data from the Clarks Fork herd paints a remarkable picture of an almost 5,000 year-old migration corridor that countless generations of mule deer have used. The implications of this idea can have profound effects on our modern understanding and management of this species. The time-depth of this behavioral adaptation can provide essential data to wildlife managers, depict how important these corridors and winter range are to these species, and highlight crucial habitats where conservation efforts must be focused. The preservation of habitat and the removal of migration barriers using modern and archaeological data to influence decision-making can profoundly impact the species.

In addition to establishing the most likely harvest scenario at the site and solidifying the importance of this area as historic mule deer habitat, we can also gain insight into the paleoenvironment. Despite the introduction of ratio variability from migratory behavior, isotope data points to an overall climate regime that includes warm and dry conditions. Drought tolerant plant species likely expanded during the time of site occupation in addition to a rise in tree lines. The relationship between carbon and oxygen isotopes indicates that mule deer spent time in closed environments, rather than open, but that the closed environments experienced drought conditions. This may seem puzzling at first, given that the dry arid environments in the region are open basins and slopes. However, the migration of deer from forested to open environments on a yearly basis may explain the dichotomy.

There is still much to learn about the mule deer population at the site from an analytical perspective. The sampled specimens account for less than 1/5 of the individuals recovered at the site, meaning that more isotopic analysis could point to more robust conclusions. This study also used bulk strontium samples that average the strontium ratios in tooth enamel. Seriation or down-tooth sampling can provide snapshots of the species' lives, specifically as it relates to migration over different bedrock. Future down-tooth sampling studies can more accurately map migration corridors and give more insight into the relationship between modern and ancient deer herds. Radiocarbon studies of sampled individuals may provide further clarity on harvest events, as will better provenience data on the original sample. Despite the shortcomings of bulk isotope analysis, this study provides a unique view into the Middle Holocene. This chapter proves how useful isotope analysis is to the interpretation of the archaeological record, even with a small sample size, and can provide a blueprint for similar studies in the future.

Chapter 7 - Conclusions

Site 48PA551 is a unique and important archaeological site that has greatly contributed to our understanding of the Middle Archaic Rocky Mountains. However, up until this point, there has been no attempt to interpret the recovered data in any theoretical framework. This dissertation marks one of the first detailed efforts to place this site into our broader understanding of archaeology in the GYE and test existing models developed by other researchers. While early conclusions about the site's function and basic archaeological assemblage are described in Frison and Walker (1984), there was never any follow-up or re-examination of the data. Over time, research trends moved on to many other important aspects of regional archaeology, and the site was all but forgotten, save a handful of mentions in various publications here and there.

Chapter 4 illustrates how to successfully "revive" archaeological sites long sat untouched by researchers. First of all, the chapter highlights how important collections research can be to modern interpretations and theoretical considerations of archaeological data. The collection's research at UWAR provided crucial data for this dissertation. The research provided a series of unpublished maps, notes, and photographs that proved vital to the horizontal provenience of the originally excavated assemblage. Many interpretations of obsidian and isotope data could not have been made if those records were not available. In fact, the obsidian and isotope datasets would be far less robust than they were if not for the collection's research, given the small-scale excavations in 2018. While the 2018 investigations were essential for better understanding the site, far less material was recovered than during the original excavations. The collection's research provided a much larger dataset without the added time and expense of excavating more material. Chapter 4 went beyond just collections research and highlighted how vital geophysical survey is to the surgical excavation of buried archaeological sites. The geophysical results presented in Chapter 4 also successfully demonstrate the ability to identify intact versus previously disturbed areas of the site when interpreted in tandem with the original records. The magnetic and GPR surveys provided important context for the modern excavations and illustrated how much can be and should be understood about the subsurface conditions before any destructive archaeological testing. While the results from Chapter 4 don’t directly impact the outcomes introduced in the hypotheses, the remaining research in this dissertation would likely have not been possible without those efforts.

The previous two chapters, specifically Chapters 5 and 6, tested specific implications of the overall hypotheses outlined at the beginning of this dissertation. To review, the overall hypotheses centered on a discussion of opposing land tenure and territoriality scenarios in addition to a discussion of the social conditions at 48PA551. The first hypothesis (H1) proposed a scenario where 48PA551 was a communal hunting ground, where groups from different social backgrounds aggregated during the winter to exploit an abundant mule deer population. Under this scenario, there would be no social boundary defense or territoriality, at least for the time of year the site was occupied. Additionally, this hypothesis suggests that communal, group hunting would have occurred, leading to the greater possibility of a mass harvest event. Obsidian sources would be quite diverse given different, distinct groups of hunter-gatherers.

The second hypothesis (H2) postulates that 48PA551 could be the location of a neutral hunting ground and an area where access was not restricted, at least during the winter season. This would mean that distinct social groups could use the area and exploit the abundant large game in the region with no social boundary defense or territoriality. However, communal hunting does not occur under this hypothesis, so the expectation of mass kill or harvest events would be unlikely to occur. Instead, the attritional accumulation of mule deer would be far more likely under these social conditions, as large-scale group hunting would not occur. Obsidian sources should still reflect diverse toolstones given the diversity of groups utilizing the site.

The third and final hypothesis (H3) diverges from the previous two and suggests that 48PA551 reflects the winter aggregation of a single social group for communal hunting. In this scenario, the winter mule deer camp is exploited by a single group where some form of social boundary defense is at play. This means that knowledge of the highly predictable mule deer is restricted to only those within the same social network. Given that a single group is aggregating during the winter, communal mule deer hunts such as drives will result in the mass harvest of mule deer. Obsidian sources in this hypothesis should not be diverse and only reflect a small number of toolstone sources.

The obsidian source results in Chapter 5 were quite useful in interpreting 48PA551 in the context of the hypotheses discussed above. Overall, there was surprisingly little diversity in the obsidian toolstone sources, highlighted by the dominance of Lava Creek Tuff obsidian. The diversity of obsidian sources was important to assess the social groups operating at 48PA551. The social makeup of the site can then be extrapolated to understand the theoretical land tenure and territoriality strategies. The dominance of Lava Creek Tuff and the relatively even dispersal of obsidians across the site at 48PA551 suggest that there was likely only one social group at the site. No clustering of specific obsidian sources was noted, though as mentioned previously, the provenience data was not as available as originally hoped. If the obsidian sources were more diverse and distributed across the site in a more patterned or clustered way, it would potentially reflect the presence of multiple groups.

Beyond the lack of diversity in obsidian sources, the factors leading to the dominant use of Lava Creek Tuff obsidian have theoretical implications. For example, the regression and chi-square analysis used to compare the expected versus observed obsidian quantities suggested that Lava Creek Tuff was over-represented no matter what the variable. As used in other analyses (such as Reckin and Todd [2019]), straight-line distance suggested that more Obsidian Cliff obsidian should be present at the site. However, given the distribution of the geological formation containing Lava Creek Tuff, the dominant obsidian could have come from an area closer to 48PA551. If we consider other factors and variables, such as those from MacDonald et al. (2019), Lava Creek Tuff is still overrepresented. This particular obsidian is lower quality, less accessible, and more expediently used toolstone than other sources in the region but is overrepresented at this particular site. This likely means that other factors are influencing obsidian choice. Considering the expectations of particular conveyance zones, social boundaries, and the single user or multiple user models previously discussed in this dissertation, we can interpret the obsidian data at 48PA551 as it relates to the established hypotheses. It seems that the residents of 48PA551 did not have unrestricted access to all obsidians in the GYE, as evident by the under-representation of Obsidian Cliff obsidian. If the GYE was a pan-Shoshonean landscape, as suggested in Scheiber and Finley (2011) and Finley et al. (2015), hunter-gatherers should have unrestricted access to high-quality obsidians. However, this is not the case. Instead, residents at 48PA551 rely on lower-quality obsidian known to come from the southern part of Yellowstone National Park. This may represent a division of social networks within the GYE and indicates that access to Obsidian Cliff may have been restricted to some groups more so than others.

Generally speaking, the obsidian results support hypothesis three (H3), given the lack of diversity in obsidian. Given the lack of other sources, the obsidian signature at 48PA551 points to one social group. Going a step further, we can extrapolate our knowledge about social conditions in the GYE, given that 48PA551 was likely only utilized by a single group. Though the site was utilized by one group, it is apparent that they had restricted access to other high-quality obsidians in the region. Therefore, at least one other group was likely operating in the region that controlled this access—controlling access to a resource such as obsidian fits well within the social-boundary defense model. This idea is supported by Reckin (2018) and Reckin and Todd (2019), who identified similar social boundaries between the Absaroka and Beartooth mountain ranges. Residents of 48PA551 likely had ties to the southern end of Yellowstone National Park, more so than to the northern part of the park given the present obsidian. Though they might have acquired some Obsidian Cliff obsidian through trade, they were likely not part of the social group who controlled access to that particular high-quality toolstone.

The isotope data obtained from mule deer teeth at 48PA551 and discussed in Chapter 6 provided evidence for specific hunting strategies and provided a glimpse into the ecology and climate of the time. The diversity of strontium, carbon and oxygen isotopes was used to assess the relatedness of the sampled mule deer. At a basic level, if the isotope signatures exhibited a great deal of diversity, the sampled deer were likely unrelated. The diversity of isotopic data directly correlates to potential prehistoric hunting strategies. If sampled mule deer are unrelated, then it is likely that the deer were harvested over time instead of in a single large event such as a deer drive. A catastrophic harvest event of a large part of a mule deer herd could likely only be completed through cooperative or group hunting, while the harvest of a few individuals here and there is much more achievable by small groups of hunters.

Overall, the isotope data overwhelming indicated that the sampled mule deer were not from the same herd. The highly variable isotope data clearly indicates that the deer came from different groups of deer occupying specific niches on the landscape. At a basic level, the isotope data support the hunting strategy in hypothesis two (H2) and the idea that deer were taken over time and accumulated at the site through attritional kill events. However, there is more nuance to the data when looking at the deer individually. A handful of the sampled deer clustered together both spatially and isotopically. The clustering indicates distinct events in which multiple related deer were taken, though not in mass. It is more than likely that small groups of hunters, or even individual hunters, harvested a small number of mule deer over multiple winters. This suggests that the deer population was quite reliable during the Middle Archaic and were exploited regularly.

The ecological and climatic implications from the isotope data aren't relevant to the hypotheses but deserve further discussion. The strontium data indicates that the deer were likely moving across the landscape at great distances, similar to what the Clarks Fork mule deer herd continues to do today. The diverse range of strontium values suggests that deer were likely traveling between the mountainous regions down to the dry basins. Given the GPS data tracking modern mule deer along this same route, it is likely that the migratory adaptation of mule deer is thousands of years old. The relationship between modern and archaeological data means that this is a vital migration corridor. Archaeological data such as this should be considered when grappling with issues in modern wildlife management. Faunal remains and isotope studies can help identify the longest-standing migration corridors for migratory species such as mule deer, elk, pronghorn, and other species and provide another avenue for identifying important habitats that should be conserved.

The oxygen and carbon data reflected a dry and xeric environment occupied by mule deer. On the one hand, these results are likely influenced by the time mule deer spent in winter range down in the basins and along the eastern, dry slopes, which fall in a rain shadow. However, given that these isotopic values are averages for the lifespan of the deer, it also means that despite what habitat they occupied, the overall climate was warm and dry. Oxygen data suggests that most water had been consumed and ingested from enriched water sources, free of the influence from snowmelt. The water sources and water obtained from leaves and other browse were likely at lower elevations or in areas with little snow runoff. The carbon data reflects an ecosystem dominated by drought-tolerant C4 grasses and habitats similar to what modern pronghorn occupy (sage-dominated basins). The ingested carbon implies that the deer were living in drought conditions where moisture was limited. While the diet of mule deer partly influences the carbon values, the values still suggest that the climate was warm and dry, no matter what habitat they lived in at any given time of year.

Considering both the obsidian and isotope data, we can draw final conclusions and discuss the hypotheses that best fit the results. Overall, 48PA551 was a winter mule deer hunting base camp occupied by a single group of hunter-gatherers who returned to the site throughout the Middle Archaic. Large, cooperative group hunting was likely not the hunting strategy employed, and instead, individuals or small groups of hunters would exploit mule deer winter range and migration routes to harvest small numbers of big game. The group likely had ties to the south and west, potentially as far as the Snake River Plain, given the presence of a Bear Gulch obsidian projectile point. The hunter-gatherers at site 48PA551 were likely not the only group operating within the GYE, a notion supported by the lack of unrestricted access to high-quality obsidians. Ultimately, the findings from this dissertation fit with parts of both hypotheses two and three.

The data supports mule deer hunting strategy in hypothesis (H2) and the social conditions of hypothesis three (H3).

This raises the possibility of a fourth strategy that can in turn be used as hypothesis to further test other archaeological sites within the GYE. The data from this dissertation reflects that 48PA551 was likely occupied by a singular group of related individuals, potentially by blood or other social connection. This group likely came back to the site over an extended period of time to exploit the mule deer and other faunal resources and harvested them in small numbers, potentially one to three at a time. Given the evidence for geophytes and tubers on groundstone artifacts, discussed at the beginning of this dissertation, the group likely came supplied with previously gathered plant and carbohydrate resources to avoid a shortfall in their diet (as discussed in Prentiss (2022) and Speth and Speilman (1983)). Though the data supports the idea that the site was occupied by a single, small group of people who harvested small numbers of mule deer year after year, they still very likely existed under social conditions where they were not the only group operating within and around the GYE. This fourth combination of subsistence strategy, social conditions, and group dynamics can be used to test other archaeological datasets within the region and assess how data aligns with our understanding of the Middle Holocene Central Rocky Mountains.

This dissertation has highlighted how archaeological research is inherently tied to other disciplines. Prehistoric archaeology cannot be conducted without first understanding the ecological conditions from which an archaeological assemblage originates. However, it is just as crucial for other disciplines to begin to see the importance of archaeological data and how it can influence research in wildlife management and ecology. Archaeological data can be used to understand the time-depth of a certain ecological phenomenon and how things have changed over time. Most wildlife management only accounts for and uses data from the last 100 years to make important decisions about habitat conservation and hunting regulations. From an archaeological perspective, researchers must make an effort to make their research more visible to the other disciplines, as there are countless opportunities to collaborate. Such collaborations can lead to much more robust and inclusive science that can influence modern public land management.

While this dissertation addressed the research questions outlined in the hypotheses, countless other questions were raised. This body of work has set the stage for a number of other avenues of research. For example, this dissertation only included mule deer in the isotope study, while other big game, especially bighorn sheep, were also plentiful in the recovered assemblage. A more robust isotope study of both mule deer and bighorn sheep can provide further data about hunting strategies by species. Additionally, down-tooth sampling of molars is crucial to better refine the migration patterns of the big game faunal assemblage. Such a sampling technique can provide seasonal snapshots of ingested strontium instead of just examining averages. In addition to more robust isotopic research, a study of toolstone diversity beyond just the volcanic toolstones can provide better context for understanding hunter-gatherer land tenure strategies. Obsidian artifacts only represent a small portion of the total lithic assemblage, and other toolstones must be brought into the study.

These future avenues of research can be accomplished through further subsurface testing at the site, given that the most recent excavations only sampled a very small portion of the site. A better spatial understanding of housepits, features, and the archaeological assemblage is needed to understand the unique nature of the site, given that the original assemblage lacks detailed spatial context. This dissertation represents a successful attempt to reassess a previously excavated site, highlighting how modern approaches to already discovered sites can lead to a wealth of new data and interpretations and presents a strong case for future work at 48PA551. I hope that this body of research can be used as a framework for future interdisciplinary archaeological research and influence others to revisit known archaeological sites using modern theoretical and methodological approaches.

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