STRATIGRAPHY, LANDSCAPE EVOLUTION, AND PAST ENVIRONMENTS AT THE BILLY BIG SPRING SITE, MONTANA

by

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ABSTRACT

This thesis reconstructs the landscape evolution of the Billy Big Spring site (24GL304, Glacier County, north-central Montana) from the last glacial maximum to present through the analysis of sediment and soil samples collected from a transect of auger tests that bisected the site and surrounding landforms. Interpretations were drawn from stratigraphy, pedologic data, sedimentologic analysis and radiocarbon dating. The site landscape came into being in the late-Pleistocene, after Wisconsin-age glaciers retreated. Glacial retreat left a meltdown depression on the land that filled with water to form a pond, which persisted through the early-Holocene. The onset of the mid-Holocene (Altithermal) occurred before ~8,415 cal. yrs. BP, when increasingly arid conditions caused the water level to drop. The first radiocarbon dated human occupation of this site occurred during the Altithermal, ~7,030 cal. yrs. BP, after the eruption of Mount Mazama (~7,633 cal. yrs. BP). Arid conditions continued until ~7,000 cal. yrs. BP, when pond water re-expanded across the basin, marking the transition to the cooler late-Holocene. Sometime before 2,100 cal. yrs. BP, dry conditions returned, and the extent of the pond water decreased again. Since this time, overland alluvial processes have deposited sediments in the basin. Many hypotheses on how the Altithermal impacted the people of the Northwestern Plains have been proposed since the 1950s, but little agreement has been reached. This is due to the fact that there was great variation in how the Altithermal expressed itself throughout the Northwestern Plains. The human reactions to this phenomena cannot be explained simplistically for the region as a whole. This study shows that the Billy Big Spring site experienced drying during the Altithermal, but despite this, people continued to occupy this site. This evidence adds to the argument that the Altithermal climate of the Northwestern Plains did not have severe enough impacts to impose much hardship on its occupants.

CHAPTER 1: INTRODUCTION

This thesis seeks to understand how landscapes and people interact in the face of climate change. This work was conducted under the assumption that components of the human environment interact to cause cultural stability and change. This is a systems approach to understanding human-landscape interactions. This approach requires utilizing data derived from multiple environmental proxies to reconstruct the past landscapes that humans occupied. Once people interact with a natural landscape, the landscape takes on cultural meaning. Geomorphology, stratigraphy, and pedology are used to understand past landscapes and their evolution, and paleobotany is used to reconstruct past vegetational regimes. This body of work applies the contextual approach to create a paleolandscape context for an archaeological site on the Northwestern Plains. The site investigated in this study is the Billy Big Spring site (24GL203) (abbreviated as “BBSs”) in north-central Montana.

The major climatic events that are of particular interest to this study include: deglaciation after the last Ice Age, mid-Holocene warming (known as the Altithermal), and the Little Ice Age. Understanding the response of the paleolandscape during these climatic events is critical for reconstructing human settlement patterns on the Northwestern Plains. The timing of deglaciation of the last Ice Age allowed for the entrance of Paleoindians into this region in the Late Pleistocene. To estimate when people may have first entered this region, it is necessary to know when the ice left and when the landscape was recolonized by plants. The Altithermal (also known as the Hypsithermal or Mid Holocene Climatic Optimum) was the warmest and driest period in the Holocene. On the Northwestern Plains the Altithermal lasted about 3,000—4,000 years. This study at the BBSs did not obtain late-Holocene stratigraphic data with high enough resolution to investigate the Little Ice Age, so the focus of the analysis is on the deglaciation and the Altithermal events.

The BBSs was selected for this analysis because previous investigations (Kehoe 2001), demonstrated it contains a series of occupations in a stratified context from the Early Archaic to the Late Precontact periods. This history of continued use through most of the Holocene showed potential to yield data about the impacts of the Altithermal. The goal of this thesis is to use stratigraphy, sedimentological and soil analyses, pollen, radiocarbon dating, and archaeological evidence as proxies to understand the landscape evolution of the BBSs. These data will be used to specifically reconstruct the post-glacial and the Altithermal environments to understand how these events affected human settlement.

This project was conducted as part of the Blackfeet Early Origins Project, which is a collaborative research project between the Blackfeet Indian Tribe, who are culturally affiliated with the ancient occupation of the BBSs, and Dr. María Nieves Zedeño from the Bureau of Applied Research in Anthropology at the University of Arizona. The project was funded with off-site mitigation funding from the Montana State Department of Transportation (Zedeño et al. 2017). Working together, Dr. Zedeño and the Blackfeet Tribal Historic Preservation Officer drafted a research plan that was of value to both the Blackfeet Tribe and university researchers. The Blackfeet were interested in investigating the nature and antiquity of their ancestral presence within the paleolandscape, and this dovetailed well with investigating the impacts of climatic events since the last glacial maximum. Together, Blackfeet tribal members and researchers from the University of Arizona excavated two 2m x 2m blocks in the summers of 2016 and 2017 (Zedeño et al. 2017). This geoarchaeological analysis was conducted to contextualize the cultural materials uncovered during the excavations.

Theoretical Background

Landscape is a central concept in this thesis. Carl Sauer (1969) is the originator of the concept of cultural landscapes. He explains that before people enter an area, the region is a natural landscape, which is composed of "materials of the earth's crust which have in some important measure determined the surface forms." (Sauer 1969:334). Once people enter the landscape, it becomes a cultural landscape. The cultural landscape is "man's record upon the landscape." (Sauer 1969:342). In this case, the natural area is the medium, culture is the agent, and the cultural landscape is the result. Following this distinction, anywhere where there is a record of man's activities (for example, an archaeological site) is a cultural landscape. More recent renditions of landscape theory view the physical environment as an active participant in the development of cultural traditions, rather than a backdrop where people imprint their activities. This view sees traditional history and culture as embedded in the land, and that cultural associations can span great geographical distances (Ferguson and Anschuetz 2003). Landscapes are the essential medium through which people sustain their cultural identities across generations (Ferguson and Anschuetz 2003). This view sees the site landscape as not just composed of physical landforms, but is a landscape imbued with meaning.

The cultural landscape of the BBSs was just one of the many localities the ancestors of the Blackfeet Tribe would have regularly visited in the past. The ancestors were big-game hunters who practiced seasonal and logistic mobility (Zedeño 2000:99). Their social environment was structured around the extraction and appropriation of localized natural resources (plants, animals, mineral, and landforms). (Zedeño 2000:98). Their lifestyle required a large area of land with many individual localities that were required for specific purposes (i.e., they offered particular resources, had spiritual importance, or were desirable locations to camp out of the weather).

The landscape approach provides a good framework to understand the network of meaningful places across the terrain this ancient group used, as opposed to viewing the BBSs as an isolated cultural site on the natural landscape. Applying the landscape approach, the total area of land used by a group composes the ‘landscape,’ and the individual localities of activity constitute ‘landmarks.’ Each landmark contributes a piece to the overall landscape story. Following Zedeño et al. (1997:126), The landscape has three different dimensions: 1) the formal, which are the physical characteristics and properties of landmarks; 2) the historical, which is the sequential network links that result from the transformation processes; and 3) the relational, which is the interactive (behavioral, social, symbolic) links that connect people and landmarks. This thesis applies the methods of geoarchaeology to understand the formal, physical characteristics and properties of the BBSs, with the understanding that these formal aspects are intrinsically linked to the historical and relational aspects of the landscape.

Since the 1980s and the rise of post-processual archaeology, archaeological studies have often been cast as either empirical or theoretical endeavors. Geoarchaeological studies have traditionally been classified as belonging to the empirical group with few theoretical applications. This does not mean, however, that geoarchaeology is atheoretical. Most geoarchaeology is conducted under a systems approach to the human environment, which is a theory borrowed from biology. Systems theory was first applied in an environmental science perspective by Chorley (1962), then from an ecological anthropology perspective by Geertz (1963), and in archaeology by Flannery (1968) (Butzer 1982). The systems approach seeks to understand how a ‘system’ works. For example; in biology, the system under study is the ecosystem, whereas in geography, the system is the interactions between human communities and their environments. In ecological anthropology, the system is the intersection of the social and environmental structures. In geoarchaeology, the system is the interactions between the biophysical environment and human society (Butzer 1982).

More recently, the basic principles of the systems approach have been reapplied in a paradigm that Butzer (1982) and Schoenwetter (1981) call contextual archaeology, which is the theory this thesis was conducted under. This theory focuses on the environmental context of archaeological finds to make interpretations. Karl Butzer posits that while it is easy to see the environment as static, the environment is actually a dynamic factor in the analysis of archaeological context. Context is a matrix of space and time dimensions, and it is key to archaeological interpretations. The ideas of the systems approach are applied in contextual archaeology to understand how the contextual components of the human ecosystem (flora, fauna, climate, landscape, and human culture) interact, leading to an explanation about cultural stability and change (Waters 1992:4). This model can be used to understand cultural stability and change based on the principle that humans develop strategies and practices to fit in their ecosystem. This model sees changes in human behavior as the result of a change in one or more of the components of the system. Understanding these interactions is the goal of applying a contextual approach. The theory of contextual archaeology fits this work because the project seeks to understand if or how environmental elements affected people. Contextual archaeology considers how different components of the environment interact to create a platform for human life. Applying the contextual approach in this project means considering all of the facets of the biophysical environment as important factors in understanding human society.

Why Geoarchaeology?

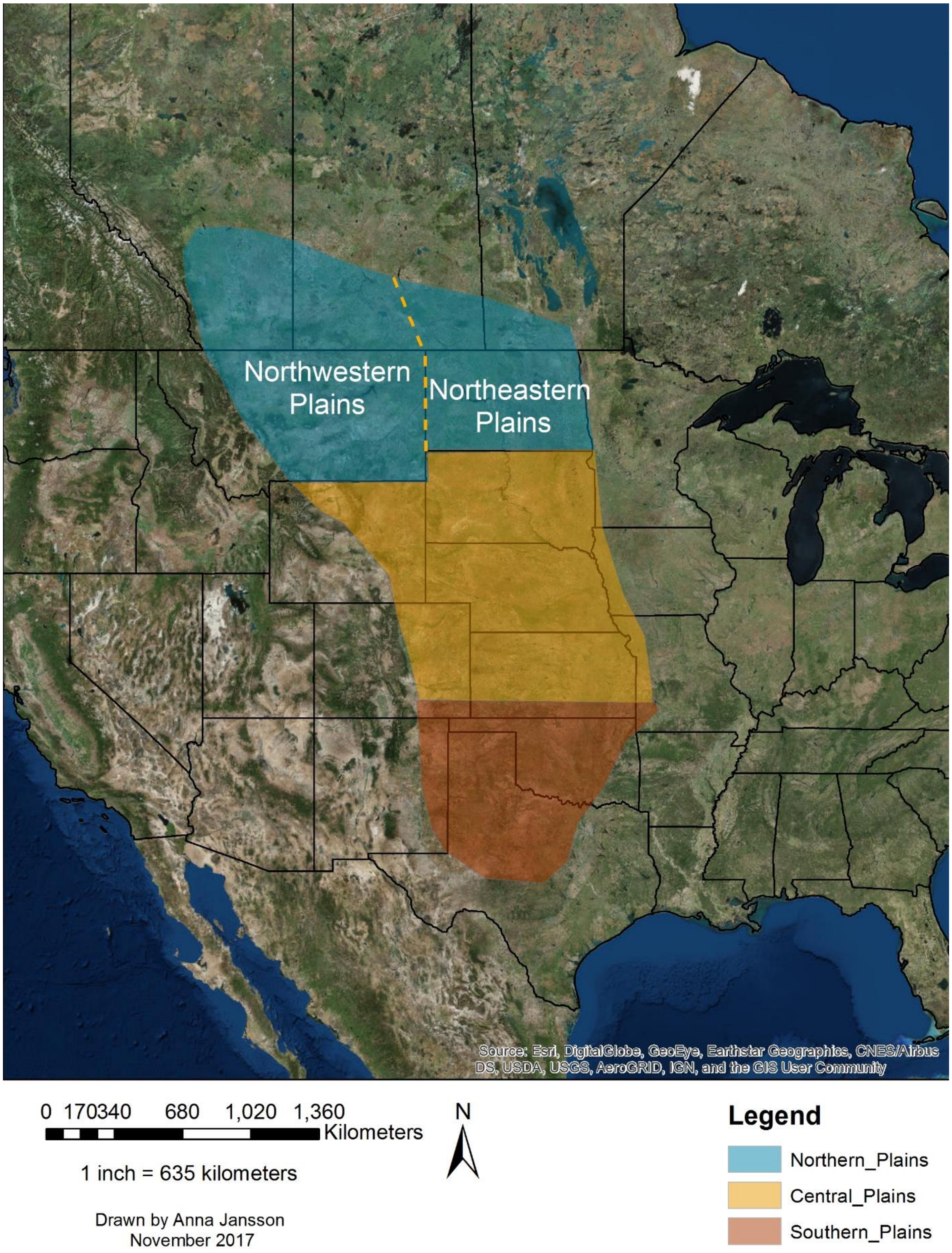
Geoarchaeology is critical to understanding the archaeological record and the human past (Rapp and Hill 2006:1). Geoarchaeology uses techniques and approaches from geomorphology, sedimentology, stratigraphy, and geochronology to investigate and interpret sediments, soils, and landforms with the goal of answering archaeological questions (Waters 1992:3—4). The primary purpose of conducting a geoarchaeological investigation is to understand the archaeology of a site, area or region using earth science-based ideas, as opposed to understanding the geology of that place with only ephemeral ties to the archaeology, which is classified as archaeological geology (Rapp and Hill 2006:2). There are four different ways that geoarchaeology is applied in the context of this study: 1) to date archaeological materials through the application of stratigraphic principles and numerical dating techniques; 2) to understand the natural and anthropogenic processes of site formation; 3) to reconstruct the physical landscape that existed around the site at the time of occupation; and 4) to reconstruct the environment at the site. Reconstructing the past environment is an important aspect of understanding an archaeological site because it places prehistoric human occupations within the context of a dynamic and evolving landscape; this, in turn, helps to elucidate human-land interactions and, in some cases, to identify causal factors that may explain culture change (Waters 1992:12).

Site Setting and History of Previous Work

Regional Context of the Northwestern Plains

The Northwestern Plains is a subdivision of the Great Plains. The Great Plains are usually conceptualized as the grassland prairie region of North America, extending from Alberta, Saskatchewan, and Manitoba in Canada, south through the west-central United States into Texas. Following Oetelaar (2011), there are three general regions within the Great Plains: the Southern

Plains (eastern New Mexico, most of Texas, western Oklahoma, southern Kansas, and Southern Colorado), the Central Plains (eastern Colorado, Wyoming, South Dakota, Nebraska, Kansas, western Iowa and western Missouri), and the Northern Plains (eastern Montana, North Dakota, southern Alberta, southern Saskatchewan and southwestern Manitoba) (Figure 1). Within the Northern Plains, there are two subregions (Oetelaar and Beaudoin 2016): the Northwestern Plains (southern Alberta, southwestern Saskatchewan, and Montana east of the continental divide) and the Northeastern Plains (North Dakota, southwestern Manitoba, and southeastern Saskatchewan).



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Drawn by Anna Jansson
November 2017

Figure 1. Map of subdivisions of the Great Plains.

Ecological Zones of the Northwestern Plains

Within the Northwestern Plains, there are three different ecological zones: the Rocky Mountain Front, the Foothills, and the Open Prairies (Oetelaar and Beaudoin 2003:188). Altitude is the most important factor for defining these zones, since altitude dictates the ecology of these areas. The Rocky Mountain Front has the highest elevation, because it is the transitional area between the Rocky Mountains (rising over 3,000 masl [Oetelaar and Beaudoin 2003]) and the lower elevation grasslands to the east. A vast variety of wetland, riparian, grassland, and forested habitats exist along the Front. The descent from the Rocky Mountains in this zone is punctuated by freestanding mountains (for example, Chief Mountain) that tower above the rest of the landscape. The Foothills are defined as the upland areas east of the Rocky Mountain Front. They have a lower elevation than the Front, with a maximum elevation of 1200 masl, but still have a varied topography of rises and drainages (Oetelaar and Beaudoin 2003). Grasslands compose mostly of vegetation cover here, with some forested areas sprinkled throughout the zone. The Open Prairies are the lowest elevation zone of the Northwestern Plains, which are generally between 800 to 1000 masl (Oetelaar and Beaudoin 2003). They have a relatively flat topography and are covered completely with grasslands. The BBSs is located on the boundary between the Rocky Mountain Front and the Foothills zones.

Geoarchaeology on the Northwestern Plains

The driving force of geoarchaeological investigations on the Northwestern Plains has been investigating Paleoindian sites (Albanese 2000). The first application of geoarchaeology on the Northwestern Plains was in 1932 to determine the age of the Scottsbluff site (Albanese 2000:239). Shortly after, Kirk Bryan conducted his pioneering study to date the Folsom component at the Lindenmeier site (Bryan and Ray 1940). After the invention of radiocarbon dating in 1950 the focus of geoarchaeological investigations expanded to studying the geomorphic and sedimentary changes during the Holocene and the development of regional stratigraphic chronologies. C. Vance Haynes' (1968) paper on arroyo cutting and filling is a classic example of this research.

Academic scientists were the primary investigators in this region before the Cultural Resource Management (CRM) boom in the 1970s (Albanese 2000:201). CRM developed after the passage of the National Historic Preservation Act of 1966 and the National Environmental Policy Act of 1969. These laws require surveys to locate and record all of the historic properties that may be impacted by federal projects, and to mitigate the adverse effects of federal undertakings on cultural materials. The number of federal undertakings needing compliance with these laws created more work than universities could handle, so private-sector contract archaeology was developed to provide the professional services needed by federal agencies. The increase in projects required more archaeologists to do the work, along with more geoarchaeology specialists to analyze sites. Considering the impacts to all of the archaeological sites in areas potentially effected by federal undertakings (rather than simply identifying archaeological sites of interest to academic archaeologists) has resulted in a larger variety of site types being investigated by geoarchaeologists than before environmental laws were passed. Originally, geoarchaeologists only worked at Paleoindian sites but now sites of all ages are investigated (Albanese 2000). Nonetheless, even though more investigations are being conducted on the Northwestern Plains, the geoarchaeology of this region is still in its infancy (Albanese 2000:239).

The Altithermal

The Altithermal Climatic Episode was originally conceptualized by Ernst Antevs (1948) as a period of drought in the Great Basin occurring from 7,000 to 4,500 years ago (5,000 to 2,500 B.C). Over the last 65 years, climate-based research has found that middle Holocene warming did occur, but that there was considerable variability in its timing, intensity, and associated ecological impacts. The global average for Holocene temperature shows a warming of about 0.6 degrees Celsius from the early Holocene to a temperature plateau spanning ~10,730 to ~6,295 cal. yrs. BP (9,500 to 5,500 ^{14}C yr BP)[1] (Lowe and Walker 2015:427), which represents an average for this event across the globe. Individual regions experienced changes much more severe or much less severe than this average. It is true that temperature did increase, but it increased by different amounts at different times across the globe (Meltzer 1999).

Even within the North American Great Plains region there is much variation in the intensity and timing of the warming (Meltzer 1999). On a gross scale, some of this variability can be explained by the longitudinal climatic variation that exists across this region. There are two important gradients in this region; precipitation decreases from east to west and temperature and evaporation rates increase from north to south. Today, as well as throughout the Holocene, these factors combine to create a general north to south gradient of decreasing effective moisture, surface water, and resource abundance. During the Altithermal, this caused increasing resource

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[1] All radiocarbon dates in this work are presented as calibrated years BP (cal. yrs. BP), accompanied with the uncalibrated radiocarbon years BP in parenthesis (^{14}C yrs. BP). Many of the dates cited in this work were published originally in ^{14}C years. To be incorporated with the other dates in this thesis, these radiocarbon dates were calibrated using the IntCal 13 curve on OxCal 4.3. In some cases, the previously published dates appeared in only in calibrated years. In these circumstances, these dates only appear here in calibrated years BP. For simplicity, the mean date of the range of calibrated dates is presented here preceded by "~" to indicate an "approximate" date. The nine radiocarbon dates that were generated from this work are presented in Table 2, with their standard error, calibrated ranges, and lab identification numbers.

patchiness, sediment weathering, erosion, and aeolian activity along this same gradient (Meltzer 1999:406).

The effects of the Altithermal were strongest on the Southern High Plains, which is a portion of the Southern Plains south of the Canadian River in eastern New Mexico and in the western panhandles of Texas and Oklahoma. Here the ground water-fed seeps and springs declined or disappeared in places as aquifer recharge failed to keep pace with discharge, and bison diminished. Additionally, isotope work suggests that the mid-Holocene landscape was marked by a rise in warm season (C_4) grasses (Holliday 1995:54—58). These changes caused the human population of the Southern High Plains to temporarily leave localized areas, dig wells to reach underground water sources, and widen their diet breadth (Meltzer 1999). There have been four sites on the Southern High Plains that have yielded hand dug wells from the Altithermal period (Meltzer 1999:408). The most extensive of these sites, Mustang Springs, had over 60 wells dating to ~7,640 to ~7,485 cal. yrs. BP (6,800—6,600 ^{14}C yrs. BP) (Meltzer 1991).

It is clear that the Altithermal had a strong ecological impact on the Southern High Plains but this cannot be projected into the Central or Northern Plains. Across the Northern Plains, there is evidence in the pollen record that this area experienced a transition to a more xeric grassland ecotone (Albanese and Frison 1995:4) but did not experience the massive decrease in available water that occurred in the Southern High Plains (Meltzer 1999:405—406). In the Northwestern Plains, multidisciplinary data indicates that an arid-to-semiarid mid-Holocene climatic episode did occur, but the botanical, faunal, geomorphic, and sedimentary responses to this event were not regionally synchronous or of the same magnitude (Albanese and Frison 1995:13). In fact, there are some sites on the Northwestern Plains (Lookingbill and Laddie Creek) where there is little evidence that the Altithermal occurred at all (Albanese and Frison 1995:13). Thus the links between the Altithermal and changes in human settlement are less straightforward on the Northwestern Plains than they are on the Southern High Plains where it is clear that the Altithermal had direct impacts to the environment and human settlement. Needless to say, the presence of surface water during the Altithermal on the Northwestern Plains is important to this discussion.

Hypotheses on How the Altithermal Affected People

The adaptive responses of human foragers to mid-Holocene climates on the Great Plains has long been a subject of discussion, if not dispute (Meltzer 1999:404). Since there was so much variation in how the Altithermal played out across the Great Plains, human adaptions to middle Holocene climate change were not consistent across regions. In fact, it is questionable if human adaptive strategies on the Central and Northern Plains were influenced at all by the scarcity of water (Meltzer 1999:409). This thesis address five previous hypotheses: 1) the Hiatus Model, 2) Reeves' idea of "no effect", 3) the Mazama Eruption Hypothesis, 4) the Foothills Hypothesis, and 5) the Altithermal Refugia Hypothesis.

Albanese and Frison (1995:1) explain that in the 1950s and 1960s the concept of the arid Altithermal and its inhospitable climate was readily accepted by Northwestern Plains archaeologists because it seemed to explain an apparent gap in the archaeological record in the Early Archaic Period. This lead to the development of the Hiatus Model by Mulloy (1958), in which he proposed the Plains were completely depopulated between 7,500 and 4,500 cal yrs. BP (5,500 BC and 2,500 BC), which roughly coincided with Antevs' (1948) Altithermal dates.

In the 1970s Brian Reeves (1973) stated that the concept of a cultural hiatus during the Altithermal has become entrenched in archaeological thought and literature. He argued that the Northern Plains were not reduced to an inhospitable desert during this time because many pollen studies had shown that a grassland existed on the Northern Plains during the Altithermal, and in turn, this grassland would have supported bison and a viable human population. He explained that the small number of sites on the Northern Plains dating to the Altithermal was attributable to sampling error in archaeological survey and site burial on the Open Prairies rather than to an actual decrease in human population. Here, this idea is referred to as Reeves' idea of "no effect". Many archaeologists agreed with this idea as they discovered areas that were heavily used by people during the Altithermal, including Creasman (1987:289) working in southwestern Wyoming and Root and Ahler (1987) working at the Benz site in North Dakota.

Archaeological sites that were occupied during the Altithermal in this region are far more common now than there were in Mulloy's time (Albanese and Frison 1995:2). Recent research conducted by Oetelaar and Beaudoin (2016) exemplifies the extent of Altithermal occupations in the Northwestern Plains. These authors compiled a list of published dates for cultural occupation in the region that pre- and post-date the Mount Mazama eruption (Figure 2). From their graph, there are at least 51 other sites that were occupied during the Altithermal timespan (~10,625 to ~6,850 cal. yrs. BP, for the Northwestern Plains). As Albanese and Frison note, archaeological research in the northwestern Plains clearly indicates that prehistoric people occupied all ecologic niches during the mid-Holocene, including the more arid portions of basins.

Some archaeologists continued to posit that the Altithermal on the Northwestern Plains had severe enough impacts that it caused a change in human settlement patterns. Some of this uncertainty is caused by the eruption of Mount Mazama (~7,633 cal. yrs. BP [Egan et al 2015]) near the end of the Altithermal. This massive eruption covered much of the Northwestern United States and adjacent regions in Canada with ash. Only recently have the potential effects caused by this eruption been seriously considered by archaeologists as the Mazama Eruption Hypothesis

(Oetelaar and Beaudoin 2005; 2016). These authors suggested that the effects from the eruption of Mount Mazama compounded pre-existing Altithermal stress and precluded human use of the Northwestern Plains region for 500 to 600 years after the eruption. They expect the area was not used for this length of time because the environment needed to recover from being smothered by the thick layer of ash fall from the eruption. Changes in settlement patterns that occurred directly after this event were originally attributed to being caused by Altithermal effects but are now realized to actually be a response to the eruption.

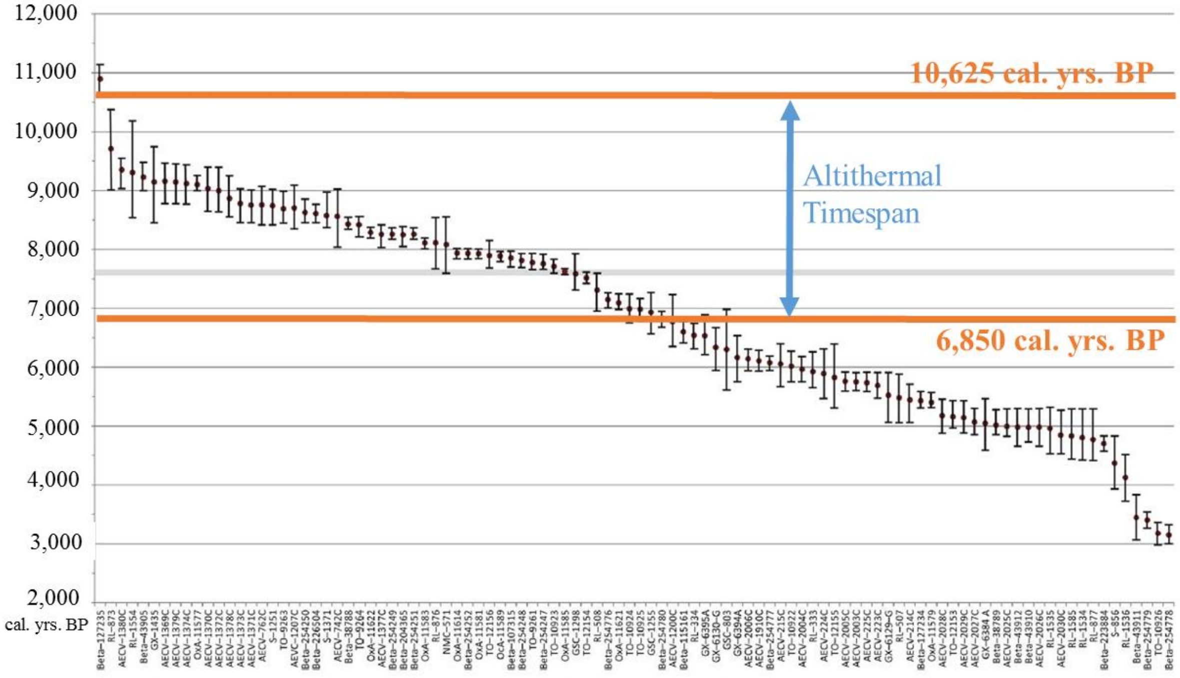


Figure 2. Radiocarbon dated occupations on the Northwestern Plains. Note that 51 occupations date to the Altithermal time span. Modified from Oetelaar and Beaudoin 2016:Figure 9.

The Foothills Hypothesis is attributed to several archaeologists (Alex 1991; Benedict and Olsen 1978; Black 1991; Greiser 1985) who hypothesized that the Altithermal climate may have reduced water sources on the Open Prairie zone of the Central and Northern Plains, causing populations in these areas to move into the Foothills and Front Range of the Rocky Mountains, since these higher elevation areas may have provided more reliable water resources. The same styles of projectile points are found within both regions, which supports this hypothesis of cultural continuity.

In the 1990s, Michael Sheehan (1994) proposed the Altithermal Refugia Hypothesis, which drew upon Hurt's (1966) idea that people may have taken refuge near rivers and springs during the Altithermal on the Northern Plains. Sheehan proposed that there were Altithermal Refugia located across the Great Plains region that would have been relatively unaffected by the warming and drying of the Altithermal Climatic Episode (Sheehan 1994:113). These refugia had reliable water sources (usually aquifer-fed springs or streams), which Sheehan hypothesized would have been more reliable than meteorological water sources (Sheehan 1994:133—134). In this model, people stayed near these 'refugia' to have access to the water. Sheehan supported this theory by explaining that Early Archaic sites across the Great Plains are usually found associated with either springs or streams (Sheehan 1995). In Sheehan's view, the smaller number of sites dating to the Altithermal supports the hypothesis that the Altithermal was indeed a time of resource stress across the Great Plains.

It is clear that the Northwestern Plains were not unoccupied for the entirety of the Altithermal, but it is not apparent if the Altithermal had any effect at all, if populations migrated into the Foothills, or if people relocated to springs and seeps to have access to reliable water sources. It is clear that the eruption of Mount Mazama impacted settlement patterns on the Northwestern Plains (Oetelaar and Beaudoin 2016), but it is unclear how severe the drought was prior to the eruption. In this thesis, the stratigraphy and archaeology of the Billy Big Spring site will be analyzed to address these five hypotheses on Altithermal impacts.

Frequency of Altithermal Aged Archaeological Sites

Understanding human responses to the Altithermal across the Great Plains is complicated by the fact that sites from this period are rare, remains are ephemeral, and the climatic context is poorly known (Meltzer 1999). It is true that there is a scarcity of mid-Holocene sites on the Open Prairie (Meltzer 1999:412) but it is unclear whether this scarcity is correlated with a reduced use of this region or is due to geomorphic processes.

David Meltzer (1999:405) points out that the scarcity of sites from the Altithermal may be due simply to erosion and deposition occurring during and after this period, which acted to remove, rework, or deeply bury archaeological features and surfaces, particularly in valleys where sites are often located. Rolfe Mandel (1992, 1995) explains that reduced vegetation cover and infrequent but intense rainfall during the Altithermal in the Central and Northern Great Plains triggered extensive erosion and sediment transport out of small tributary upland valleys. This caused Altithermal-age surfaces in larger and deeper valleys (which may have been frequented by human foragers due to their persistent water sources) to be eroded, carried downstream, deposited in disarray, and deeply buried. Additionally, Anderson and coauthors (1989:524) point out that because lake levels were lower during the Altithermal, archaeological sites would have existed adjacent to these lower lake edges. After the Altithermal when the lake level rose, the Altithermal-aged archaeological sites would have been eroded and inundated by the rising water levels. The apparent increase in sites after the Altithermal may reflect better archaeological visibility due to a different suite of geomorphic processes (Meltzer 1999). These geomorphic effects make understanding patterns in Altithermal archaeology even more difficult.

Previous Work at the Billy Big Spring Site

The BBSs was originally excavated by Thomas Kehoe in the 1950s. Kehoe found a remarkable artifact record in apparently stratified deposits but conducted no geoarchaeology. This work revisits BBSs to contextualize its cultural materials in a paleolandscape reconstruction. Kehoe conducted three seasons of excavation (1952, 1954, and 1971) on the southwest side of a ponded landform, which he interpreted as the remnants of a kettle lake (Kehoe 2001:27). Kehoe defined five cultural occupations at the site, with diagnostic stone tools spanning from the Early Archaic to the Late Prehistoric period. Kehoe's artifact analysis focused on the point types within each occupation, but other stone tools, flakes, and faunal bones were also uncovered during his fieldwork. The oldest horizon (Level 1) was found within a matrix of glacial till and contained modified flakes and charred and cut animal bones. Level II had one symmetrical lanceolate point. Level III (Mid Archaic) contained Oxbow, Meron, and Gowen points. Level IV (Mid-Late Archaic) contained Pelican Lake and Besant points, as well as one Sandy Creek complex point. Level V (Late Precontact Period) contained one Prairie side-notched point along with a feature composed of water-rolled and fire cracked rocks and slabs of sandstone obliquely placed at a 45-degree angle to the ground (Kehoe 2001:32). Kehoe was uncertain of the function of this feature. In total, Kehoe recovered 41 whole projectile points, 9 projectile point fragments, 125 whole and fragmentary scrapers, 51 knife blades and fragments, 37 cores, 3 gravers, 11 choppers, one abrader, 2 drills, and 5 shaft scrappers (Kehoe 2001:32). A total of 285 artifacts were recovered from the excavation. Kehoe also collected several unproveienced artifacts as surface finds at the site.

BBSs is important for the Northwestern Plains because there are few sites within the region that exhibit a well-stratified series of continuous occupations since the Early Archaic.

This long history of use makes this site a good location to investigate how settlement changed over time. Additionally, Early Archaic period sites are few along the Rocky Mountain Front, so BBSs presents a special opportunity to study this period and to investigate Altithermal impacts in this ecological zone.

Research Questions

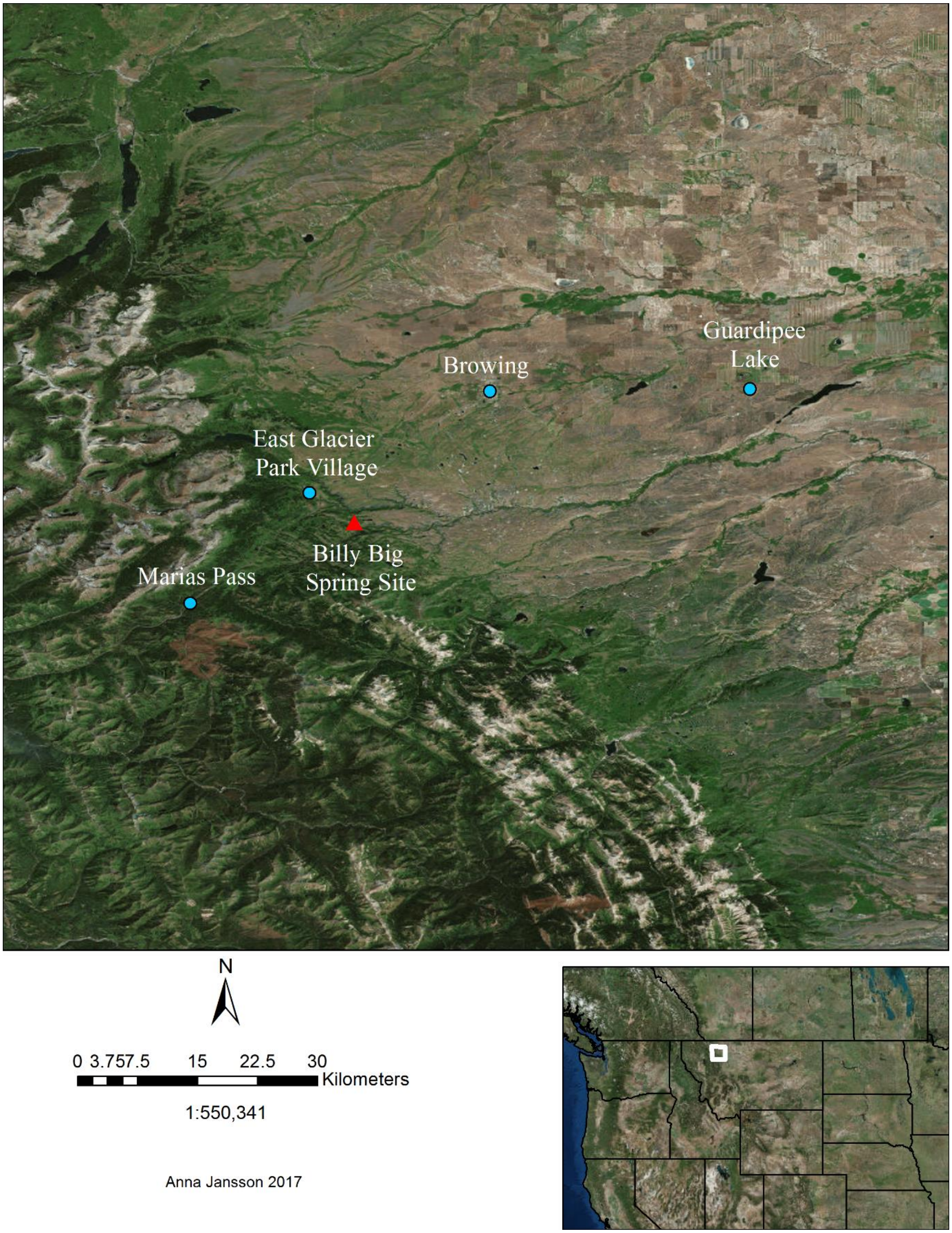
This thesis applies the landscape approach (Zedeño 2000), the theory of contextual archaeology (Butzer 1982) and the method of geoarchaeology to develop a site-specific history of landscape evolution and site formation at a multi-component, clearly stratified archaeological site. It demonstrates how and why BBSs provides clues to paleoenvironmental change and human adaption through the Holocene. The research questions guiding this investigation are: 1) *How does water arrive in the pond basin at the site?;* 2) *What was the paleolandscape like during the post-glacial period and Altithermal periods?* and; 3) *How does the BBSs fit into the five previously proposed models of Altithermal impacts to human settlement on the Northwestern Plains*? Because research on these topics is limited, this thesis has implications relevant to the broader region.

CHAPTER 2: SITE SETTING

The Billy Big Spring site (BBSs) is located on the present-day Blackfeet Indian Reservation in north-central Montana, near the town of East Glacier (Figures 3 and 4). It sits on a high bluff overlooking the South Fork of the Two Medicine River, at the convergence of an aspen forest, a pine forest, and a grassland. Surrounded by ridges on the west, north, and east and by a sharp drop on the south, the site is well protected from the strong winds of the Great Plains. At the same time, BBSs commands a great view of the forested slopes of the Rocky Mountain Front and the South Fork, making it an ideal place to watch the movement of people and game.

Bedrock

Bedrock affects geomorphology, so a brief mention of the underlying bedrock of this region is warranted for a discussion of its landscape evolution. Across the Great Plains, the underlying bedrock is mostly shallow marine sedimentary material from the Phanerozoic time, the age of which becomes younger to the south and west (Holliday et al. 2002:335). The mountains that bound this study area to the west (the Lewis Range) consist of Precambrian Belt Supergroup sedimentary and metasedimentary rocks (Karlstrom 2000:179). The Foothills and plains east of the Lewis Range are developed on Tertiary and Cretaceous sandstones and shales (Karlstrom 2000:179) and this is where the BBSs is located. The BBSs is located on the Blackleaf Formation, which is composed of mudstone interbedded with layers of sandstone (Cannon 1996b) (Figure 5). This formation is only exposed in the high mountains and Foothills of the Blackfeet Indian Reservation; in the plains to the east it is deeply buried (Cannon 1996b). Across most of the reservation, the bedrock is overlain by unconsolidated Quaternary or Tertiary deposits (Cannon 1996a).



Anna Jansson 2017

Figure 3. Location of 24GL304. Note the proximity of this site to the towns of East Glacier Park Village and Browning. Guardipee Lake (the location of Barnosky's (1989) pollen study) and Marias Pass (location of Carrara's (1986, 1989) work) also occur on this map. Aerial imagery is an ESRI basemap available in ArcGIS 10.4.

Figure 4. Overview of BBSs. View looking west. Photographed by Anna Jansson, July 2016.

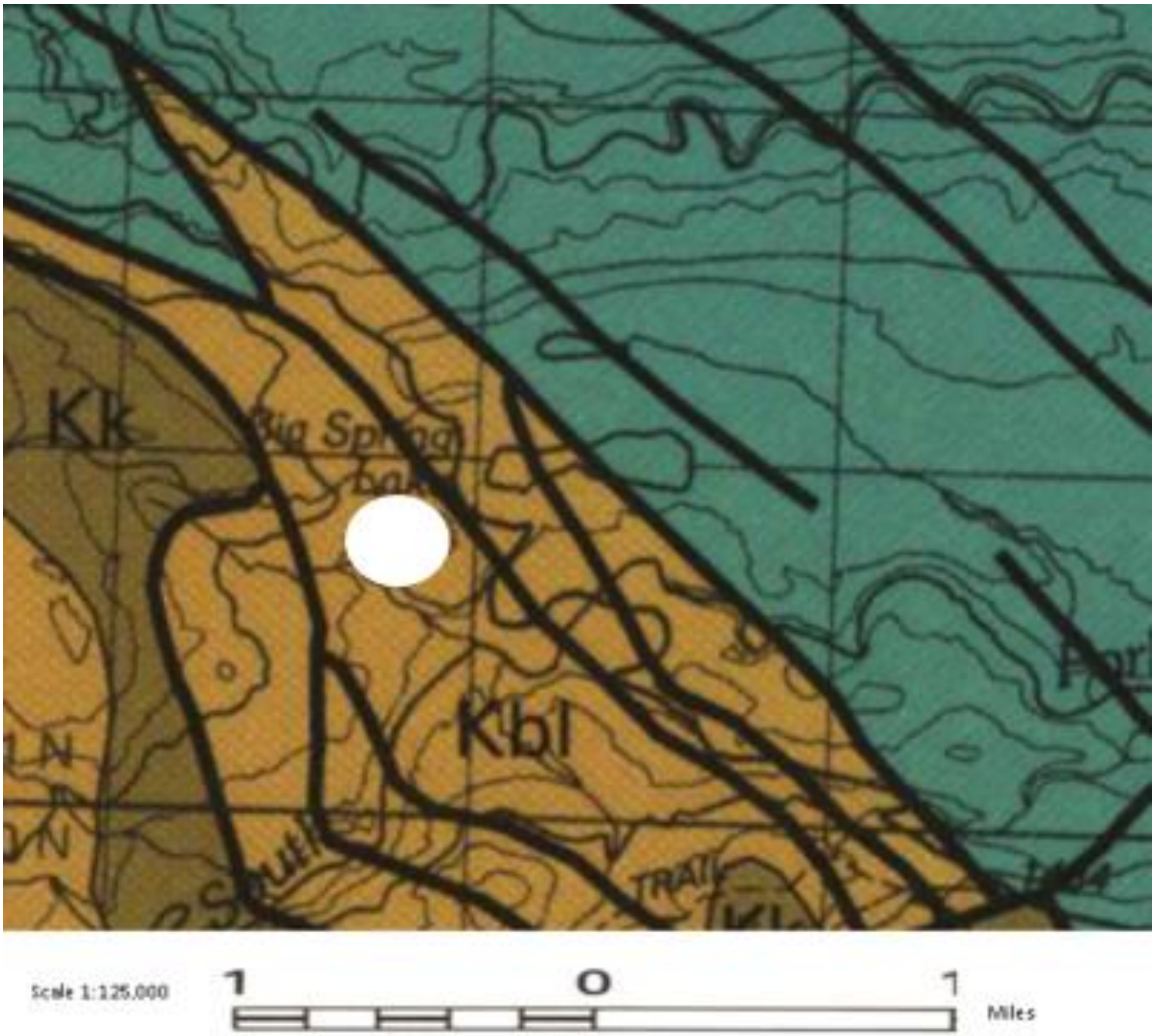


Figure 5. Bedrock geology near the Billy Big Spring site. "Kbl" is the "Blackleaf Formation," "Kk" the Kootenai Formation, and the blue/green color represents the Marais River Shale. Modified from Cannon (1996b:Plate2).

Glacial Geology

The glacial history of this area is important for this investigation for two reasons. First, this landscape was uninhabitable during the Last Glacial Maximum (LGM) when it was covered with ice. Only after the glaciers retreated into the mountains could this area support plant and animal life. Second, the erosional and depositional forces of the glaciers created a hummocky terrain that allowed a pool of water to collect at this site, drawing animals and people here.

During the LGM, most of the Northwestern Plains was covered by the Laurentide Ice Sheet, which reached its maximum extent around 23,360 cal. yrs. BP (Fullerton et al. 2004:11). At roughly the same time, the Pinedale glaciation occurred in the Rocky Mountains, though it exhibited its own local advances and retreats. Each lobe of ice that reached the plains from the Rocky Mountains left its own geologic history in glacial till deposited across the landscape. The lobe that covered the area of the Billy Big Springs site is called the Two Medicine lobe. The Two Medicine lobe flowed out from coalesced alpine glaciers in Marais Pass, a mountain pass on the Continental Divide directly south of Glacier National Park and west of the Billy Big Spring site (Figure 2), eastward onto the Plains of Montana (Carrara et al. 1986 and Fullerton et al. 2004:4).

The Two Medicine lobe had three separate maxima, all of which covered the Billy Big Spring site: Pinedale 1, 2, and 3 (oldest to youngest) (Figure 6). The Pinedale 1 maximum was the largest, extending 55 km beyond the mountain front (Carrara et al. 1986), and encompassing 2,000 km^2 (Alden 1932 and Calhoun 1906). The maxima of Pinedale 2 and 3 were each progressively smaller. Radiocarbon dates for the maxima of Pinedale 1 and 2 are 26,160 to 25,700 cal. yrs. BP, and 23,860 to 22,900 cal. yrs. BP, respectively). For the Pinedale 3 maximum, geologists know that it was significantly older than late Pinedale valley-glacier drift, which dates to 17,640 to 17,520 cal. yrs. BP, and younger than the Pinedale 2 maximum (Fullerton et al. 2004:12).

Between the Pinedale 2 and Pinedale 3 maxima, the active terminus of the Two Medicine piedmont lobe retreated back into the Rocky Mountains, perhaps as far as Marias Pass (Fullerton et al. 2004:12). This would have exposed the Billy Big Spring site for a period between the two maxima. The third and final advance of the glacier likely was due to mass-balance changes in the northern Montana ice field associated with dissipation of the ice field rather than climate change

(Fullerton et al. 2004:12). The end of the Pinedale glaciation is relatively dated to sometime before ~13,250 cal. yrs. BP (11,400 ^{14}C yrs. BP), which is when Marias Pass became ice-free (Carrara et al. 1986, Carrara 1989). This date is based on the Mount St. Helens Jy eruption. Ash fall from this eruption is preserved in Marais Pass, which means that the pass was ice free by the time the eruption occurred (Carrara et al. 1986, Carrara 1989). In Washington, near the town of Colville, Carrara and Trimble (1992) dated ash from the Mount Saint Helens Jy eruption to ~13,863 cal. yrs. BP (12,000 ^{14}C yrs. BP), but they admit that this earlier date is an anomaly, and is not congruent with the accepted date for this eruption (Carrara and Trimble 1992:2404). Ashes from Mount Saint Helens Jy and Glacier Peak G are usually preserved together in a couplet (Carrara et al. 1986). Glacier Peak G is securely dated to ~13,076 cal. yrs. BP (11,200 ^{14}C yrs. BP), and it is well accepted that the Mount Saint Helens Jy eruption happened shortly before this (Carrara 1989).

Till from alpine glaciers in this region is usually much rockier than till from the Laurentide Ice Sheet. For example, Karlstrom (2000:180—181) observed Rocky Mountain tills to be composed of 40 to 50 percent Belt Supergroup sedimentary rocks in a sandy loam matrix, whereas tills from the Laurentide Ice Sheet usually have a clayey texture, containing only 2 to 5 percent rocks, usually both smaller and more rounded than clasts found in the Rocky Mountain glacial tills. The landforms created by glacial retreat are responsible for creating a place that people from Paleoindian to Late Precontact times wanted to live.

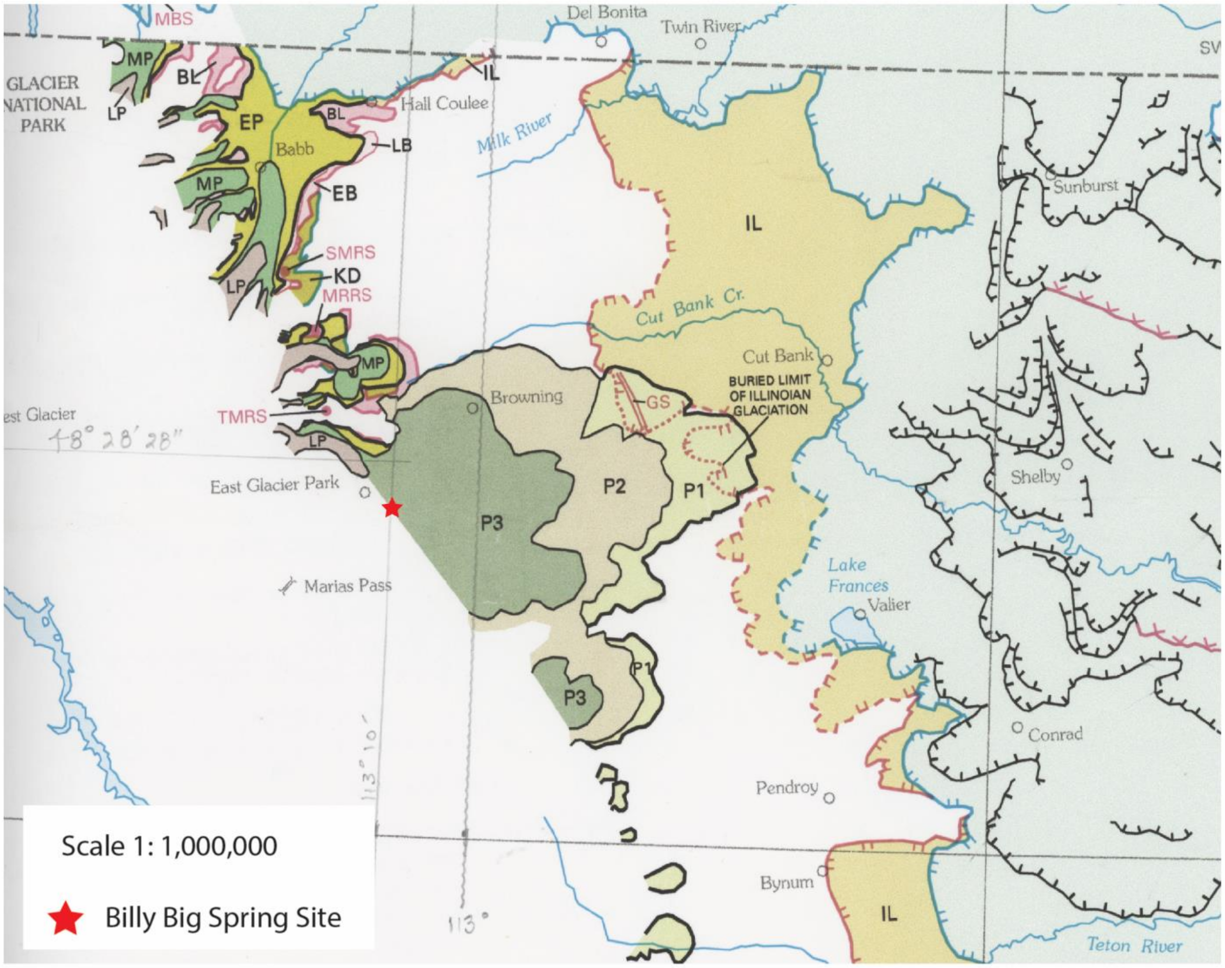


Figure 6. Map showing three Pinedale maxima in relation to the Billy Big Spring site. "P3", "P2", and "P1" represent the Pinedale 3, 2, and 1 maxima, respectively. Modified from Fullerton et al. (2004:Plate 1).

After deglaciation, herbaceous tundra would have revegetated the landscape within a few hundred years, and forests would have regenerated by 1,000 years, if not much sooner (Potter et al. 2017:10). It is clear that trees had already recolonized Marais Pass before the time of the eruptions because Carrara (1989) found a conifer needle, an alder strobili, and an unidentifiable wood fragment beneath a deposit of Glacier Peak G ash, and several small willow fragments beneath Mount St. Helens Jy ash in Marias Pass. Taking this into consideration, Marias Pass was likely ice free for a long period of time (perhaps as much as a 1,000 years) before the ~13,250 cal. yrs. BP Mount Saint Helens Jy eruption. It appears that the Marias Pass area had a substantial vegetation community by ~13,250 cal. yrs. BP, which would have served as a habitable environment for animals and people.

Formation of the Pond Basin

As the Two Medicine lobe retreated it left a veneer of hummocky till over the area, characterized by micro-highs and micro-lows. The latter resulted in the formation of small glacial ponds and lakes, which are ubiquitous across this region of Montana. Glacial till is a good aquifer, resulting in precipitation-fed springs that water these drainage basins (Cannon 1996). It is within and around one of these small basins that the Billy Big Spring site is located (Figure 7). Kehoe referred to the landform at this site as a kettle lake (Kehoe 2001:27). This pond was formed by the same ice stagnation processes that form kettle lakes, just on a smaller scale. Characterizing this landform as a 'meltdown depression' perhaps more accurately reflects its size.

The rocky alpine glacial till that surrounds the site has high groundwater permeability and holds large groundwater aquifers. According to Cannon's (1996a) surficial geological map of Blackfeet Indian Reservation (Figure 8), the BBSs is located on top of 'Quaternary landslide deposits'. Most of these deposits are formed from piedmont glacial till, but potentially could have originated from a range of other sources including gravel terraces and pediments, sediments deposited in glacial lakes, rock and surficial debris in landslides, and alluvium in the channels and floodplains of streams. Water arrives in the basin at this site as spring discharge from the underlying glacial till aquifer and through overland flow from the surrounding uplands.

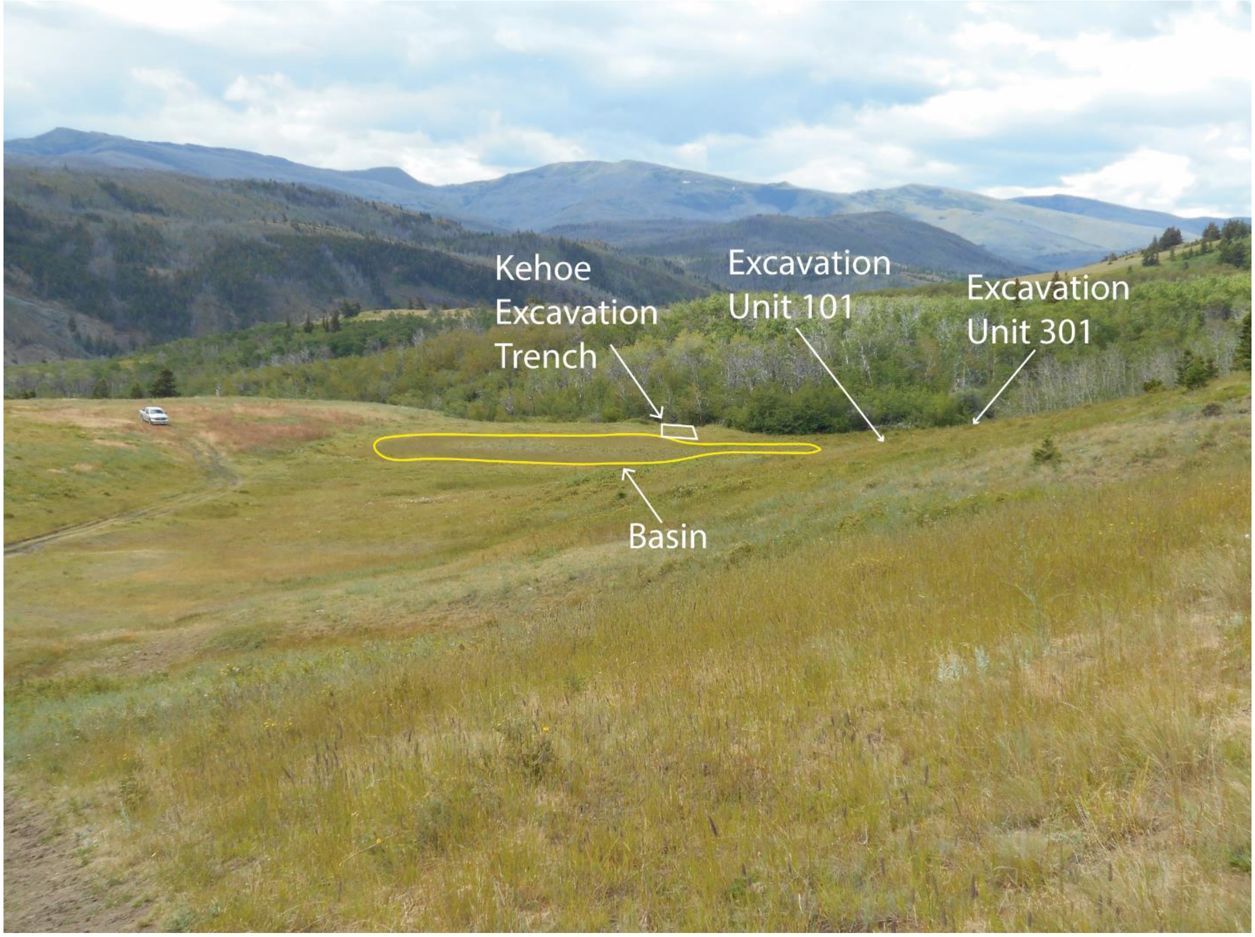


Figure 7. Site overview showing expanse of the pond basin and location of excavation units. Photographed by Anna Jansson in July 2016.

In the summer of 2016, when this work was conducted, the weather was dry and the pond was completely desiccated into a hardened, dry clay surface. In the wet season and during wetter summers, a pond or marsh forms in the basin (María Nieves Zedeño and Vance Holliday, personal communication 2016). The wetland at this site was likely a magnet for animals, and provided a good place for people to camp. At this location in the Foothills of the Rocky Mountains, the eastern Prairies are just beginning to transition into forested mountain environments. Today, an aspen stand lies to the west of the site, and a pine forest uphill to the north. Most aspen in this area are a historic addition to the biome so it cannot be assumed that this aspen stand was present during earlier than a few hundred years ago.

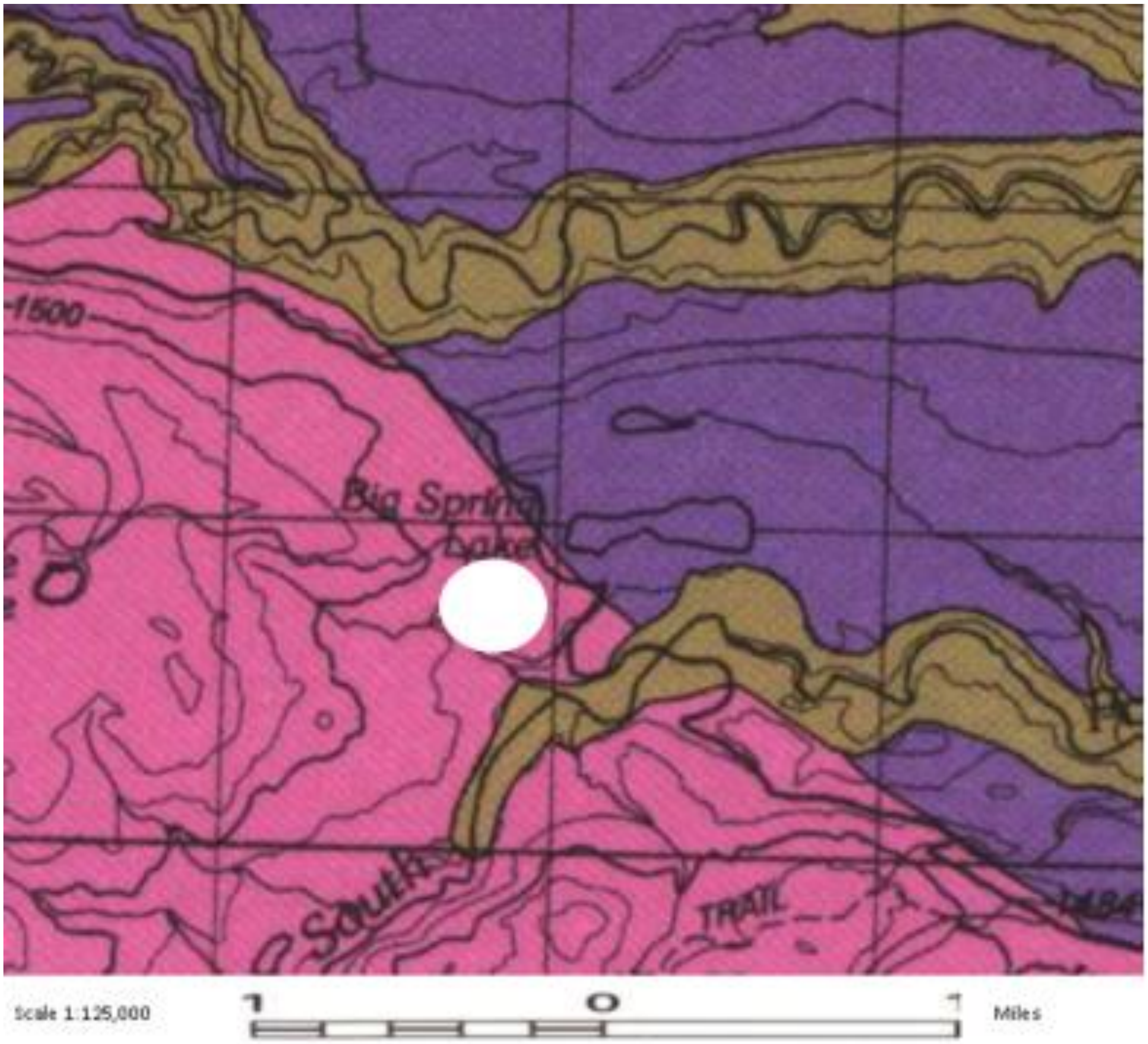


Figure 8. Surficial geology around the Billy Big Spring site, marked with a white circle. Pink represents landslide deposits and till, purple represents till deposited by piedmont glaciers, and tan represents bedrock. Modified from Cannon (1996a:Plate 1).

Climate History

A key component of this research deals with understanding how people at the BBSs responded to environmental change; in particular, to climate change. To build a context for this discussion, a brief summary of what is already known about climate change in this region is warranted. The climate history is given in four sections; 1) Late Pleistocene; 2) early-Holocene;

3) mid-Holocene; and 4) late-Holocene. A date of 11,700 cal. yrs. BP (10,000 ^{14}C yrs. BP) is used as the temporal boundary between the Pleistocene and Holocene (Walker et al. 2009).

A tripartite early, middle and late subdivision of the Holocene is commonly used. In North America, the climatic changes associated with the divisions of the early-, mid-, and late-Holocene are regionally dependent. A working group of the International Commission on Stratigraphy (ICS) has recently proposed a formal subdivision of the Holocene Series/Epoch, but this proposal has not been formally ratified (Walker et al. 2012). The proposed subdivision places the Early-Middle Holocene Boundary at 8,200 cal. yrs. BP, and the Middle-Late Holocene Boundary at 4,200 cal. yrs. BP (Walker et al. 2012). This thesis acknowledges this proposal, but bases the subdivisions of the Holocene on local stratigraphic and paleobotanical records rather than the proposed ICS standard.

Generally, the division between the early- and mid-Holocene is seen as a shift from the cool and moist conditions of the early-Holocene to a more arid climate of the mid-Holocene. In the Northwestern Plains, this occurred between ~10,625 and ~7,575 cal. yrs. BP (9,400—6,700 ^{14}C yrs.), depending upon location (Albanese and Frison 1995:1). The most appropriate date for the early- to mid-Holocene transition at the BBSs is 10,625 cal. yrs. BP (9,400 ^{14}C yrs. BP), which Cathy Barnosky (1989) determined through pollen analysis at Guardipee Lake (only 40 kilometers east of the BBSs). The division between the mid- and late-Holocene is commonly seen as a return to cool conditions, but is also occasionally characterized as the advent of the Neoglaciation (Albanese and Frison 1995:1). Across the Northwestern Plains, cooling associated with the mid- to late-Holocene transition occurred between ~7,830 and ~2,550 cal. yrs. BP (7,000—2,500 ^{14}C yrs. BP) (Albanese and Frison 1995:1). This study considers the transition to a cooler climate as the mid- to late-Holocene boundary as opposed to the Neoglaciation, since the Neoglaciation occurred very late in Glacier National Park between ~490 and ~240 cal. yrs. BP (400 and 100 ^{14}C yrs. BP) during the Little Ice Age (Albanese and Frison 1995:1). This date is so recent that it would cast most of the Holocene as the mid-Holocene, and leave very little of the record as the late-Holocene. The most relevant date for this transition comes from Barnosky's (1989) work at Lost Lake, which places the transition at ~6,850 cal. yrs. BP (6,000 ^{14}C yrs. BP). Under this scheme, the late-Holocene contains several individual episodes of climate change. It commenced with cooling after the mid-Holocene, was then followed with a transition to medieval warmth, then cooled again at the Little Ice Age, and then another return to warm conditions.

Late Pleistocene: LGM—11,700 cal. yrs. BP (LGM—10,000 ^{14}C yrs. BP)

The BBSs lies on the Foothills, halfway between the heavily forested slopes of the Rocky Mountains and the grasslands of the Open Prairies. Paleoenvironmental research has been conducted in both Rocky Mountains and Open Prairie, but not in the Foothills. The Late-Pleistocene paleoenvironment of the BBSs likely fell somewhere between the paleoenvironments of the two studied ecological zones. Cathy Barnosky's study of two pollen cores from Guardipee and Lost Lake documents the Late Pleistocene paleoenvironment of the Open Prairies. Her study analyzed vegetation changes on the Open Prairies over the last ~14,100 cal. yrs. BP (12,200 ^{14}C yrs. BP). She found that by ~14,800 cal. yrs. BP (12,200 ^{14}C yrs. BP), significant warming had already occurred at Guardipee Lake (Barnosky 1989:71). The low percentages of arboreal pollen from this time suggested that the area around Guardipee Lake has been a temperate grassland with shrubs growing locally in mesic settings for the last ~14,100 cal. yrs. BP (12,200 ^{14}C yrs. BP), although its character and that of the nearby montane forests have changed (Barnosky 1989:64). Between ~14,100 and ~13,340 cal. yrs. BP (12,200 and 11,500 ^{14}C yrs. BP), Barnosky

(1989:64) saw evidence for a high rate of sediment inwash and sparse vegetation, which likely reflect mass wasting on the recently deglaciated landscape before enough vegetation was established to hold the sediments in place.

This is different from the paleoenvironmental history of the Rocky Mountains in Marias Pass, where Paul Carrara (1989) found that trees had already colonized the area by 13,240 cal. yrs. BP (11,400 ^{14}C yrs. BP). Additionally, Carrara's (1989) pollen data also indicate that at the time of these eruptions the treeline was 500 to 700 meters lower than it is today. The paleolandscape of the BBSs during the late-Pleistocene fits between the Guardipee Lake and Marais Pass paleoenvironmental reconstructions, though it is spatially closer to Carrara's Marias Pass work. Based on this, it is likely that the BBSs was a mostly forested landscape during the early-Pleistocene, with some grassland areas.

Late Pleistocene in Nearby Regions

Catherine Yansa (2007) conducted an extensive study on preserved pollen and plant macrofossil remains from two lakes in North Dakota. Her findings are relevant to this work, but because they originate from a considerable distance from the BBSs (on the Northeastern Plains), they are less directly applicable than Barnosky's and Carrara's data. Yansa found that lake levels were high during this time but that precipitation regime was low. Instead, surface water originated from the melting Laurentide ice sheet. This residual meltwater effect diminished during Pleistocene-Holocene transition, but it buffered vegetation from the low precipitation regime. Additionally, Yansa found that during late-glacial and early postglacial times on the Northeastern Plains, summer temperatures were about 2 degrees Celsius lower than modern (pre 1800 A.D.) temperatures and winter temperatures were 8 degrees Celsius colder. This was because summertime insolation was greater than it is now, causing winters to receive correspondingly less insolation. This was caused mainly by the jet stream pattern at the time, which hugged the southern margin of the Laurentide Ice Sheet, and deflected moist air to the south. Climate close to ice sheet would have been mild during the summers and brutally cold in the winter. It is likely that a similar situation existed on the Northwestern Plains as well.

Younger Dryas

In some regions of North America, cooling associated with the Younger Dryas time period occurred around 12,900 to 11,700 cal. yrs. BP (11,000 to 10,000 ^{14}C yrs. BP). McGregor et al. (2011:86) found evidence for this event in their analysis of a lake core from Swiftcurrent Lake in Glacier National Park. Using %TOC, C/N ratios, and grain size of clastic sediments, these researchers show that between 12,900 and 11,500 cal. yr BP this region was under a colder and possibly drier climate relative to the rest of the Holocene. On the Open Prairie, Yansa did not see evidence for Younger Dryas cooling in her pollen analysis. The Swiftcurrent Lake study is closer regionally to the BBSs than the Northeastern Plains, so the BBSs probably saw Younger Dryas affects more akin to Swiftcurrent Lake.

Early-Holocene: 11,700– ~10,625 cal. yrs. BP (10,400—9,400 ^{14}C yrs.)

The changes associated with the shift to warmer and drier conditions during the late-Pleistocene to Holocene transition greatly accelerated hillslope erosion and caused major valley alluviation to dominate early-Holocene environments on the Northwestern Plains (Knox 1983:35—36). McGregor et al. (2011) found that the land along the Rocky Mountain Front experienced complex landscape instability due to variable climatic and geomorphic conditions in the early- and mid-Holocene, 11,300 to 7,500 cal. yr BP (McGregor et al. 2011:87). Data from central Alberta shows rapid warming at the end of the Last Glacial Maximum represented by a rapid invasion of arboreal vegetation around ~13,100 cal. yrs. BP (11,300 to 11,200 ^{14}C yrs. BP) (Vickers 1986). Additionally, other studies in the Rocky Mountains have suggested that the

Early Holocene was a time of increased seasonality (Elias 1996), with some areas exhibiting either extreme wet or dry summer months (Brunelle et al. 2005). In short, there was much mass wasting on the landscape during the early-Holocene, but vegetation was also quickly taking root and working to slow erosion.

Mid-Holocene (Altithermal): ~10,625— ~6,850 cal. yrs. BP (9,400—6,000 ^{14}C yrs. BP)

Recent research in the Northern Plains region has found that the Altithermal occurred slightly earlier here than in other regions (Yansa 2007). The timing of the Altithermal on the Northwestern Plains is transitional between the Pacific Northwest (where it occurred earlier) and the Midwest (where it occurred later), but contemporaneous with the Kanasaskis Valley in southwestern Alberta (Barnosky 1989:70). Montana and Wyoming appear to have experienced a similar Altithermal timespan, represented by a more xeric climate between ~10,625 to ~7,840 cal. yrs. (9,400 to 7,000 ^{14}C yrs. BP) (Albanese and Frison 1995). East of this study location, Rolfe Mandel found evidence of the Altithermal initiating at 8,000 cal. yr BP at the Beacon Island site in North Dakota (Mandel et al. 2014), which is later than the Northwestern Plains. This gradient of warming corresponds to the how rapidly the Wisconsin ice sheets retreated from these areas (Yansa 2007), and the air circulation patterns that flowed off of the receding ice (Vickers 1986).

In the Great Basin, the Altithermal was a mid-Holocene phenomenon, but in the Northwestern Plains, it occurred in a timespan that is more conventionally associated with the early-Holocene (Walker et al. 2012). Barnosky's (1989) pollen work from Guardipee Lake found the Altithermal signature on the Northwestern Plains to be almost 3,600 calibrated years earlier than the traditional Antevs (1948) date for the initiation of Altithermal. Barnosky's date was 10,625 cal. yrs. BP (9,400 ^{14}C yrs. BP), whereas Antevs' was 7,000 cal. yrs. BP (5,000 cal.

B.C.). Additionally, Barnosky found that the Altithermal ended on the Northwestern Plains 2,300 calibrated years earlier than Antevs' date. Barnosky's date was ~6,820 cal. yrs. BP (6,000 ^{14}C yrs. BP), whereas Antevs' was 4,500 cal. yrs. BP (2,500 cal. B.C.). The Northwestern Plains regional-specific dates are applied in this study as the beginning and end of the mid-Holocene.

There is huge variation in the timing of the Altithermal in western Montana. The vegetative responses to the onset of a drier climate have been observed between ~10,625 to ~6,850 cal. yrs. BP (9,400 to 6,000 ^{14}C yrs. BP) on the Open Prairies of northwestern Montana, to ~8,888 to ~4,470 cal. yrs. BP (8,000 to 4,000 ^{14}C yrs. BP) in the Elkhorn Mountains of Southwestern Montana, while in the western-most mountain range in Montana, the Bitterroots, the Altithermal did not initiate until ~7,840 cal. yrs. BP (7,000 ^{14}C yrs. BP) (Albanese and Frison 1995:13). From eastern to western Montana (340 km), there is a 2,400 ^{14}C yr time lag in the onset of xeric conditions reflected in the pollen record (Albanese and Frison 199:13). The length of the Altithermal period also greatly varies from 2,600 to 4,000 ^{14}C yrs. (Albanese and Frison 1995:13). In general, Kutzbach (1987) estimates that the annual temperature during the Altithermal in the northwestern United States (between 9,000 and 6,000 ^{14}C yrs. BP) was 2 degrees Celsius warmer than present.

Barnosky (1989) found that after ~10,510 cal. yrs. BP (9,300 ^{14}C yrs. BP) the Northwestern Plains experienced an increase in *Chenopodiaceae/Amaranthaceae* pollen and a decline in *Artemisia*, which indicates the development of xerophytic (dryland-adapted) grassland at the beginning of the Altithermal. The Lost Lake core supports this drying trend by showing that by ~10,625 cal. yrs. BP (9,400 ^{14}C yr BP) this area was a xeric grassland with a climate drier than the present. Most rainfall during this time occurred in the summer months (Barnosky 1989).

Knox hypothesizes that sediment yields and valley alluviation may have also declined during droughts on the northwestern Plains (Knox 1983:35).

Even locations in the same region experienced vastly different timing of Altithermal climate change. For example, analyzing Swiftcurrent Lake in Glacier National Park, McGregor et al. (2011) the warmest and most stable period of the Holocene to be from 7,000 to 4,000 cal. BP. This is substantially later than the dates documented in most of the other work on the Northwestern Plains. At the Indian Creek archaeological site (24BW626), located in the Elkhorn Mountains of southwestern Montana, the pollen record shows an abrupt change from a subalpine coniferous forest to a sagebrush steppe at ~8,820 cal. yrs. BP (8,000 ^{14}C yrs. BP) (Fredlund and Bozarth 1987, as cited in Albanese and Frison 1995). This shows a somewhat similar transition to the increased aridity of the Altithermal. The HacHaffie archaeological site, just 40 km northwest of the Indian Creek site, shows a shift to Altithermal conditions at ~9,280 cal. yrs. BP (8,280 ^{14}C yrs. BP) with an increase in sagebrush pollen (Davis et al. 1991). Anderson et al. (1989) explain that paleoenvironmental studies in Alberta have shown that mid-Holocene warming exhibited very similar timing and effects in Alberta as it did in Montana and Wyoming as a 3,000 to 4,000 year-long warm period with a dry climate generally ranging between ~10,330 and ~6,630 cal. yrs. BP (9,200 and 5,800 ^{14}C yrs. BP). They explain that the Altithermal caused significant changes to surface hydrology and vegetation, as exemplified at Lofty Lake (in east-central Alberta), where pollen and stratigraphy indicated that the lake was reduced to a shallow pond surrounded by wetland soil from ~9,460 to ~7,180 cal. yrs. BP (8,700 to 6,300 ^{14}C yrs. BP).

A volcano in Oregon also catastrophically erupted during the Altithermal. This volcano, Mount Mazama, was located in western Oregon in the Cascade Range. Its eruption occurred sometime between 7,682—7,584 cal. yr. BP (Egan et al. 2015) and covered much of northwestern North America with ash. This eruption surely impacted the climate of Northwestern North America for a while after the eruption. Drawing from their excavations in Alberta, Oetelaar and Beaudoin (2005; 2016) hypothesize that this eruption killed plant life and, combined with the pre-existing stress of the Altithermal, forced people to temporarily leave the Northwestern Plains until the vegetation could regenerate, which probably took about 500 to 600 years.

Barnosky saw the end of the Altithermal at ~6,882 cal. yrs. BP (6,000 ^{14}C yrs. BP), when shrubs spread and the forests expanded, which indicates cooler and moister conditions than previously. Anderson and coauthors conclude that the Altithermal ended with an increase in precipitation or a decrease in summer temperatures, or both (Anderson et al. 1989:524).

Altithermal in Adjacent Regions

Yansa's (2007) pollen analysis shows that around ~10,190 cal. yrs. BP (9,000 ^{14}C yrs. BP) the Northeastern Plains experience a shift from white spruce forests to deciduous hardwoods. This change has long been attributed to a warming climate. This warmer climate during the deciduous parkland phase brought with it the first noticeable draw down of the regional water table, which created vast tracks of forage for migrator herbivores. The presence of mudflats and the precipitation of carbonate-rich marl support a lowering of the water table. Drying lake beds would have provided good forage for bison. These data are significant because they show how the increasingly arid climate of the mid-Holocene was actually a benefit to the people of the Northern Plains, as opposed to a handicap.

Late-Holocene: ~6,850 cal. yrs. BP—present (6,000 ^{14}C yrs. BP—present)

The end of the mid-Holocene was not a synchronous event throughout the Northwestern Plains but rather seemed to have been a gradual long-term process (Albanese and Frison

1995:15—16). This change to a less arid and cooler climate is usually signified with a decrease in erosion, slope stabilization, and widespread pedogenesis (Albanese and Frison 1995:16). Barnosky's (1989) pollen data shows that after ~6,882 cal. yrs. BP (6000 ^{14}C yrs. BP), more wet habitats existed that supported shrubs and that forests expanded into the nearby mountain ranges. She interprets this onset of cooler and moister conditions as indicating the end of Altithermal period. Several widespread erosional episodes occurred in the late-Holocene during brief returns to aridity (Albanese and Frison 1995:16). These erosive episodes were severe because plant cover had decreased during the Altithermal, and there was little vegetation to stop erosion (Knox 1983:35). This episode of massive erosion caused many drainages on the Montana plains to become entrenched down to the bedrock beneath the surficial Holocene sediments, a condition still visible on the landscape today.

Since about ~6,850 cal. yrs. BP (6,000 ^{14}C yr. BP), ice buildup in the Rocky Mountains has tended to be correlated with river entrenchment on the Plains and glacial retreat with alluviation (Knox 1983:36). Knox proposed three main episodes of erosion of early- and mid-Holocene alluvium for the Northwestern Plains. The first occurring between ~6,850 and ~5,170 cal. yrs. BP (6000 and 4500 ^{14}C yrs. BP), the second from ~3,670 to ~1,945 cal. yrs. BP (3,400 to 2,000 ^{14}C yrs. BP) and the third currently taking place since ~665 cal. yrs. BP (700 ^{14}C yrs. BP) (Knox 1983:36). These erosion episodes are likely responsible for removing large tracts of early archaeology from the region, and burying them in disarray downstream. Significantly, at Swiftcurrent Lake, McGregor et al. (2011) found evidence for the growth and increase in erosive power of the Grinnell Glacier (in Glacier National Park) between 3,800 and 2,800 cal. yr BP, which is roughly congruent with Knox's second episode of erosion on the Northwestern Plains.

Barnosky (1989:70) saw even further cooling since ~3,670 cal. yrs. BP (3,400 ^{14}C yrs. BP), with a decline in *Chenopodiaceae/Amaranthaceae* and an increase in pine. The Northwestern Plains continued to experience climatic change throughout the late Holocene, including the Medieval warm period, the Little Ice Age, and historic alpine glacial melting in the Rocky Mountains (McGregor et al 2011). Valley alluviation was the dominant process for most of the last 700 years, but may have ended with the entrenchment of channels during the late nineteenth century (Albanese and Wilson 1974).

Culture History

Many cultural chronologies have been proposed for the Northwestern Plains. This work uses the chronology put forth by George Frison (1991), with slight modification (Figure 9). Frison's chronology is as follows: Paleoindian, Early Plains Archaic, Middle Plains Archaic, Late Plains Archaic, Late Prehistoric, Protohistoric, and Historic. In this work, the "Plains" modifier is dropped from the three Archaic periods because it is redundant. Also, "Late Prehistoric" is replaced with "Late Precontact" to recognize that Native American oral traditions include historical accounts.

The use of the terms "protohistoric" and "contact period" have recently been debated in Northwestern Plains and Rocky Mountain archaeology (Scheiber and Finley 2012). These authors feel that designating "protohistoric" and "contact" periods obscures the archaeology of this time. They explain, that by designating these artificial boundaries, archaeologists cast everything that occurred during these times as the initial reaction to European people and take away Indian decision making during this time and do not acknowledge long-term indigenous histories (Scheiber and Finley 2012:357). Scheiber and Finley (2012:357) recommend presenting chronologies with calendrical dates, as opposed to cast them into these misleading categories.

Since this thesis is aimed towards the general reader who does not command an extensive knowledge of Northwestern Plains history, the old terminology of “protohistoric” and “historic” are used to give a rough idea of what was going during these times, but is not meant to be the sole descriptor of what was occuring during these periods.

The oldest archaeological site on the Northwestern Plains is Wally’s Beach in Alberta, Canada. This site contains the butchered remains of seven horses and one camel in association with 29 nondiagnositic lithic artifacts (Waters et al. 2015). Twenty-seven radiocarbon ages date this site to ~13,300 cal. yrs. BP, which predates the oldest firm date for Clovis (13,085 to 12,915 cal. yrs. BP) (Waters et al. 2015:4265). The Clovis culture may extend further back in time, making it unclear if the Wally’s Beach site represents a pre-Clovis or Clovis kill.

There are many Early, Middle, and Late Paleoindian sites in the Northwestern Plains, belonging to the cultural complexes of Clovis, Goshen, Folsom, Agate Basin, Hell Gap, Cody, Frederick/James Allen, Lusk, Foothill/Mountain, Alder and Hardinger, Lovell Constricted, Pryor stemmed, and Deception Creek (Kornfeld et al. 2010). Projectile points dating to the Paleoindian period are typified by their use of high-quality lithic material and craftsmanship. In this region of Montana, Clovis-age lithics have a strong focus on local material types, which is different than the rest of North America (Ives et al. 2014). Since the early discoveries of Paleoindian artifacts in association with megafauna remains, it was assumed that Paleoindians were big game hunters. The high visibility of megafauna remains has caused a disproportionate representation of Paleoindian sites with megafauna, as opposed to Paleoindian sites with only lithic and small animal remains. More recent literature recognizes that Paleoindians likely also utilized plants and smaller-sized animals for food. The Paleoindian period spans roughly 13,000 to 8,390 cal. yrs. BP on the Northwestern Plains (Kornfeld et al. 2010).

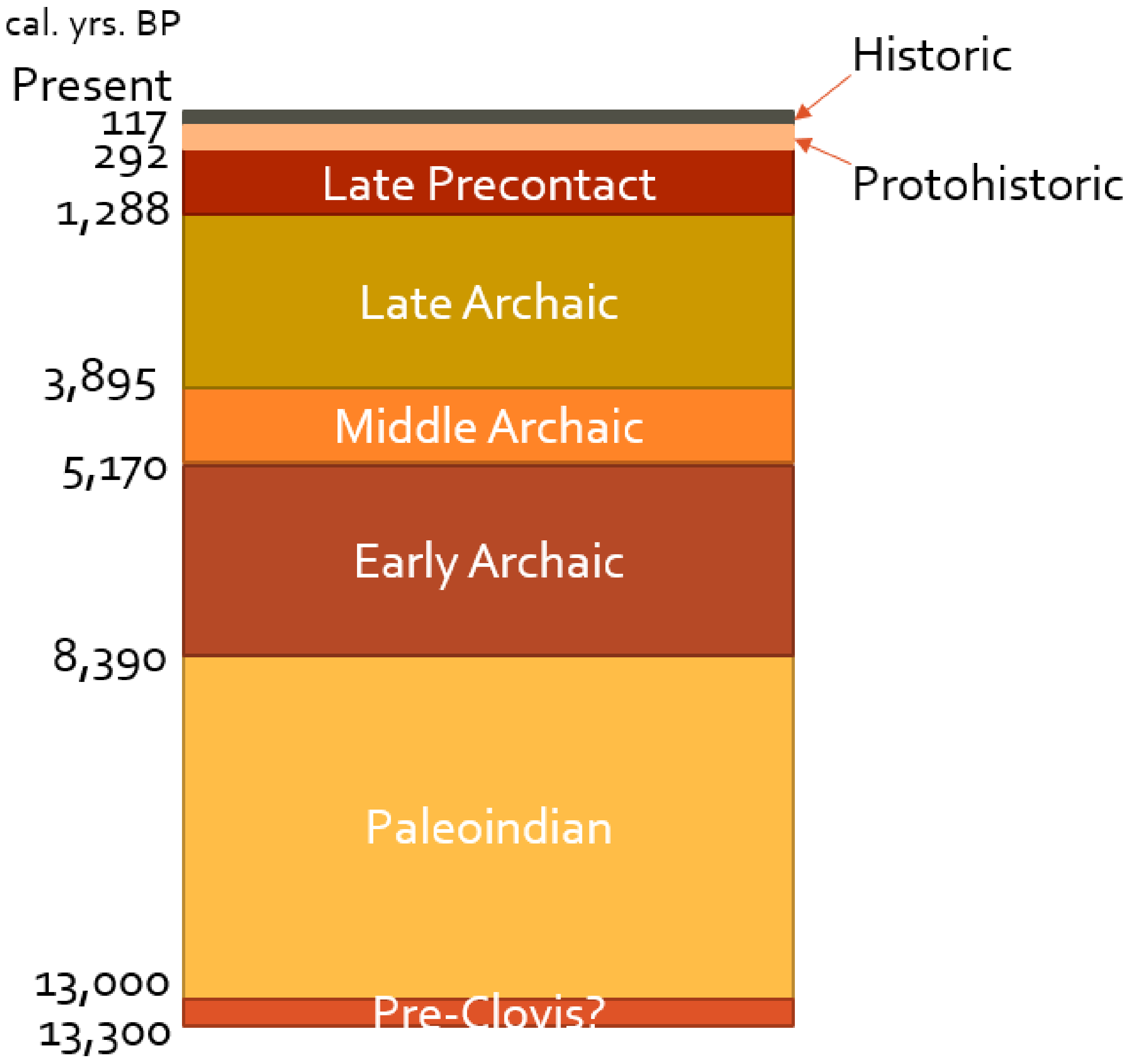


Figure 9. Cultural chronology used in this thesis.

The shift from the Paleoindian period to the Early Archaic is marked by the transition from lanceolate and stemmed projectile points of the Late Paleoindian period to the side-notched types of the Early Archaic (Kornfeld et al. 2010:106). Oxbow points appear towards the end of the Early Archaic and persist on the Northern Plains through the Middle Archaic. The Early Plains Archaic spans from ~8,390 cal. yrs. BP (8,000 to 7500 ^{14}C yrs. BP) (Kornfeld et al. 2010:107) to ~5,170 cal, yrs. BP (4,500 ^{14}C yrs. BP) (Albanese and Frison 1995).

The Middle Archaic is marked by the abrupt and widespread appearance of the McKean Complex around ~5,170 cal. yrs. BP (5,500 ^{14}C yrs. BP) (Albanese and Frison 1995) that lasted until about ~3,895 cal. yrs. BP (3,600 ^{14}C yrs. BP) (Peck 2011). This complex is characterized by an exponential increase in the number of prehistoric sites, the appearance of abundant grinding stones, large numbers of roasting pits, more emphasis on food plant procurement and, stone circle habitation features (Albanese and Frison 1995:2).

The beginning of the Late Archaic is marked by a transition to Pelican Lake projectile points Plains ~3,895 cal. yrs. BP (3,600 ^{14}C yrs. BP) (Peck 2011), which are the oldest of several styles characterized by open corner notches that form sharp points or barbs as they intersect blade edges and bases (Kornfeld et al. 2010). Around ~2000 cal. yrs. BP, the Besant projectile point appeared in the Northwestern Plains (Kornfeld et al. 2010:125). This point style is represents an extremely sophisticated bison hunting manifestation (Ibid). The Late Archaic lasted until about ~1,288 cal. yrs. BP (1,350 ^{14}C yrs. BP) (Peck 2011).

The Late Precontact Period is marked with the occurrence of the Avonlea projectile point, followed by the Plains Side-Notched point. Most archaeologists attribute this change in point style to the introduction of the bow and arrow. The Late Precontact period spans ~1,288 cal. yrs. BP (1,350 ^{14}C yrs. BP) to 292 cal. yrs. BP (1725 AD) (Kornfeld et al. 2010:130, 136). Bison jumping became a widespread practice during this period, as documented at the Vore Site in the Wyoming Black Hills area (Kornfeld et al. 2010:131).

The Protohistoric period is marked with the introduction of the horse, which in the Northwestern Plains is roughly dated to the first quarter of the eighteenth century (292 cal. yrs. BP, or 1725 AD) (Kornfeld et al. 2010:135). Dempsey's (1994:27) Blackfoot informants indicated that the horse arrived among their people about A.D. 1725. This is concurrent with when Shoshoneans also obtained horses (Kornfeld et al. 2010:135). Protohistoric sites sometimes contain projectile points that were constructed out of repurposed metal obtained from trade with Europeans. The Protohistoric period ends when Europeans permanently settled in the area. This did not occur in the Western Plains or Rocky Mountains until late in the 19th century, in fact, townships were not founded in Montana or Wyoming until the early 1900s (Scheiber and Finley 2012:348). For simplicity, the transition to the historic period is placed at 117 cal. yrs. BP (1900 AD) here.

CHAPTER 3: METHODS

To restate, the questions guiding this research are: 1) *How does water arrive in the pond basin at the site?;* 2) *What was the paleolandscape like during the post-glacial period and Altithermal periods?* and; 3) *How does the BBSs fits into the five previously proposed models of Altithermal impacts to human settlement on the Northwestern Plains*? To address these questions a variety of field and laboratory analyses were applied.

Sediment Sample Collection

The soil samples required for geoarchaeological analysis were collected using a standard soil auger. This type of auger is capable of removing short cores (less than 25cm in length, with a 10 cm diameter) from the surface downward. The auger cannot dig through cobbles, meaning that very rocky substrates are impassable in this type of coring. The length of the core we were able to extract with each draw varied with the texture of the matrix being excavated. It was difficult to extract full-length cores from coarse, cobbly sediments because larger clast sizes are more difficult to dig into. The average draw of the soil auger dug about 11 cm into the ground, with a range between 3 and 24 cm. Moist, clay-dominated sediments produced the longest, most intact cores. Sometimes soil would slump into the auger test from the overlying layers during digging. These slumped sediments were discernable from intact sediments because they were loosely compacted, whereas the intact sediments were still compact inside the auger barrel. Only the obviously intact sediments were characterized.

Auger Test Locations

To create a landscape context for the site, it was important to analyze stratigraphy from areas inside and outside of the site boundaries. Archaeological sites are often situated at unique locations on the landscape, for example, a spring or place of resource abundance. For this reason, the stratigraphy of an archaeological site may not reflect regional geomorphic trends, making it important to look at the stratigraphy outside the site to gain a full understanding of the geomorphological context (Holliday 2004:30). Furthermore, human activities at a site may have modified the sediments, so it is important to compare intra- verses extra-site (Stein 2001:21). To gain a landscape perspective of BBSs, a transect of five auger tests were dug that spanned the glacial pond basin, and incorporated areas that were within and exterior to the site (Figure 10). The augers tests in the transect are numbered 2, 6, 7, 8 and 9. Augers 1, 3, 4, and 5 were initiated, but had to be terminated at a shallow depth due to blockage by cobbles. These tests were disregarded. The auger holes included in the transect ranged in depth between 148 and 297 cm. Digging was terminated when cobbles that blocked the auger were encountered.

All of the sediments that were excavated from the auger tests were laid out on a tarp in stratigraphic order. Obviously slumped sediments were removed at this point. After each core segment was removed, the depth of the auger hole was measured. The sediment from each auger draw was individually characterized with Munsell color and texture-by-feel (Figure 11 to Figure 15). Laboratory particle size measurements are far more accurate than the texture-by-feel method for determining sediment compositions. The original field measurements are presented here, but the final interpretation were made from the laboratory particle size analysis when possible.

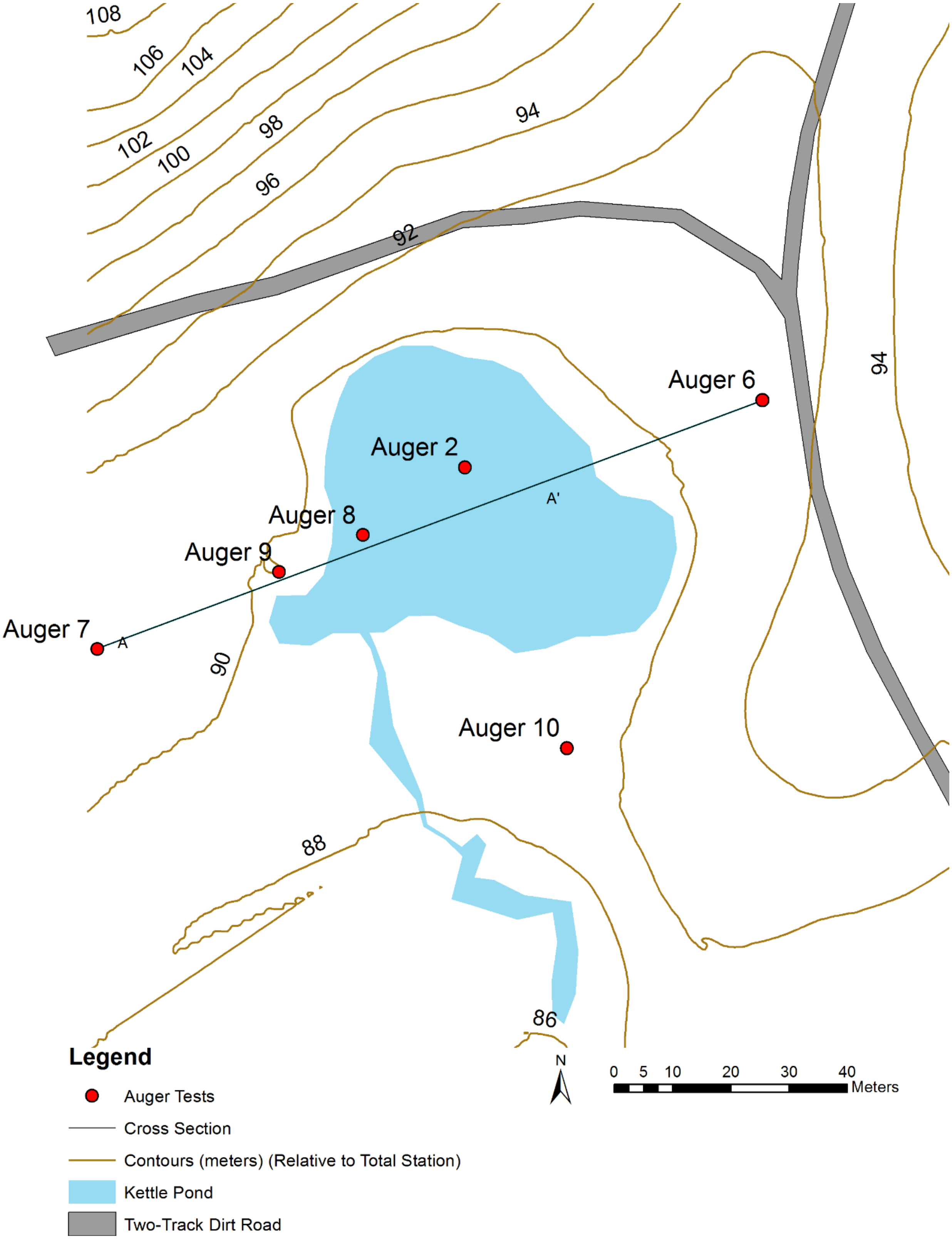


Figure 10. Auger test locations. "Blocks" are 2m x 2m excavation blocks.

Description

0-23:10 YR 2/1 Black, Si Cl Lo

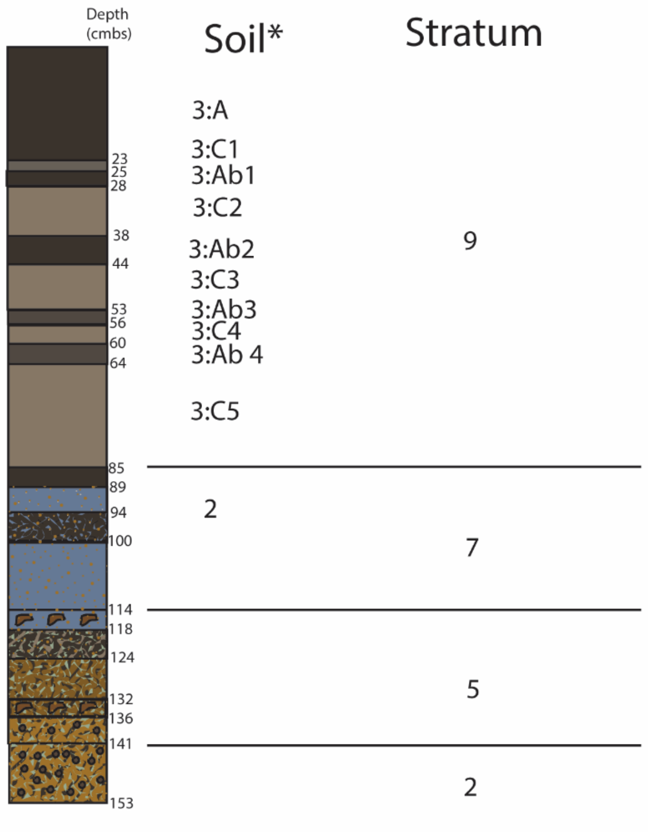
23-25: 10 YR 4/1 Dark Gray, Cl Si
25-28: 10 YR 2/1 Black, Si Cl Lo
28-38: 10 YR 5/2 Grayish Brown Cl Si

38-44: 10 YR 2/1 Black, Si Cl Lo

44-53: 10 YR 5/1 Gray, Si Cl
53-56: 10 YR 3/1 Very Dark Gray, Si Cl Lo
56-60: 10 YR 5/1 Gray, Si Cl
60-64: 10 YR 3/1 Very Dark Gray, Si Cl Lo

64-85: 10 YR 5/1 Gray, Si Cl

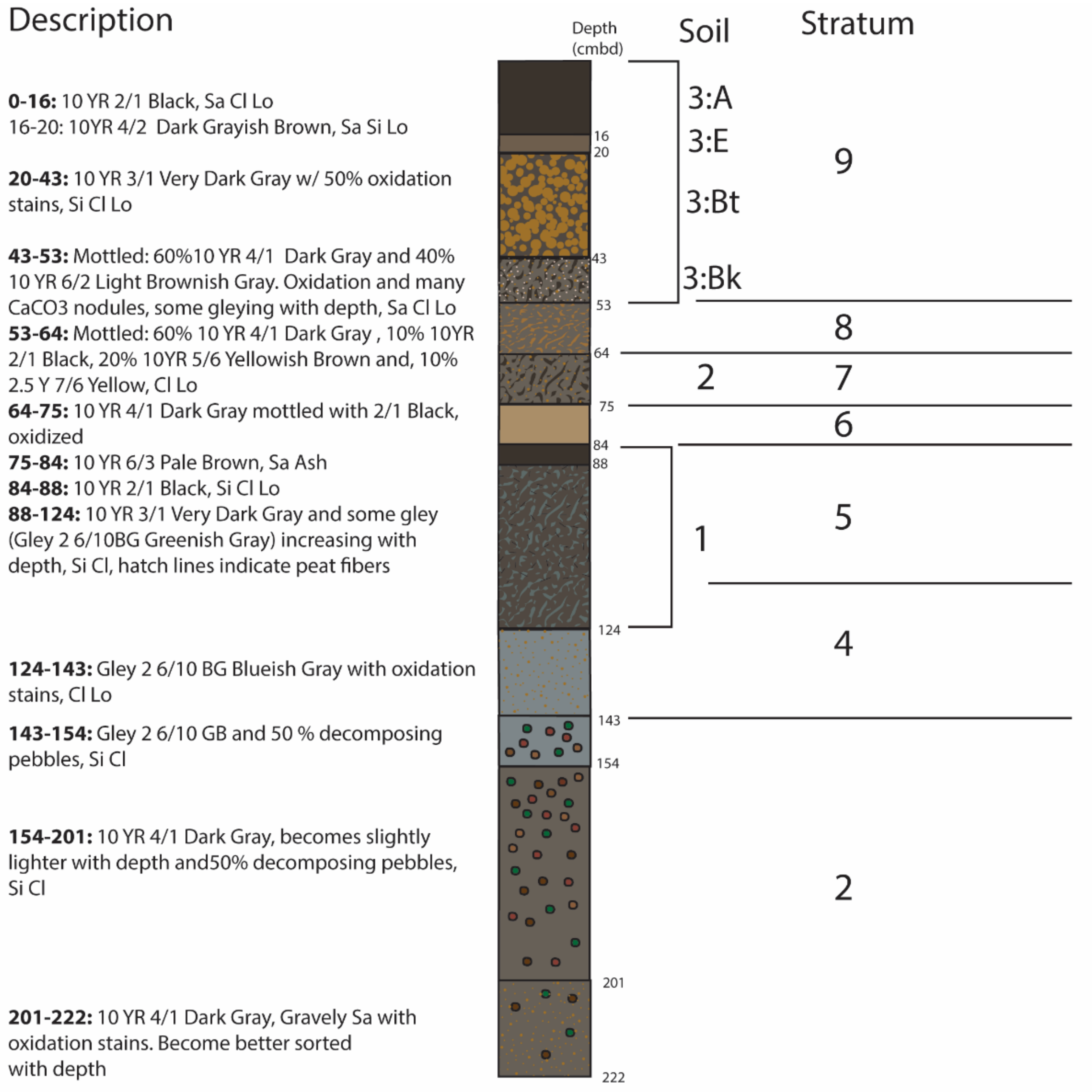
85-89: 10 YR 2/1 Black, Cl Lo
89-94: Gley 1 6/1 Greenish Gray with oxidation and CaCO3 nodules, Si Cl
94-100: 10 YR 2/1 Black mottled with Gley 1 6/1 with oxidation, CaCO3 nodules and, peat fibers, Si Cl
100-114: Gley 16/10Y Greenish Gray, oxidaion Si Cl
114-118: Gley 1 6/10Y with oxidation, Si Cl
Gley 1 6/10Y and 20% large cobbles, oxidation, and peat fibers, Si Cl
118-124: 10 YR 2/1 mottled with 10 YR 5/2 Grayish Brown and Gley 2 6/5BG Greenish Gray, oxidation stains, Si Cl
124-132: 10YR 4/6 Dark Yellowish Brown mottled with 10YR 5/1 gray and, Gley 2 7/5BG Greenish Gray, Si Cl
132-136: Same as above, but with 20% gravel
136-141: 10 YR 5/8 mottled with Gley 2 6/BG Greenish Gray and 10 YR 5/3 Brown, and15% pebbles, Si Cl
141-135: Same colors as above, but with 50% pebbles



Abbreviation	Texture
Sa	sandy
Si	Silty
Cl	Clayey
Lo	Loam

*Soils are indicated first with a number representing the individual soil profiles, followed with the horizon

Figure 11. Field observations for Auger 7.



Description

0-16: 10 YR 2/1 Black, Sa Cl Lo
16-20: 10YR 4/2 Dark Grayish Brown, Sa Si Lo

20-43: 10 YR 3/1 Very Dark Gray w/ 50% oxidation stains, Si Cl Lo

43-53: Mottled: 60%10 YR 4/1 Dark Gray and 40% 10 YR 6/2 Light Brownish Gray. Oxidation and many CaCO3 nodules, some gleying with depth, Sa Cl Lo
53-64: Mottled: 60% 10 YR 4/1 Dark Gray , 10% 10YR 2/1 Black, 20% 10YR 5/6 Yellowish Brown and, 10% 2.5 Y 7/6 Yellow, Cl Lo
64-75: 10 YR 4/1 Dark Gray mottled with 2/1 Black, oxidized
75-84: 10 YR 6/3 Pale Brown, Sa Ash
84-88: 10 YR 2/1 Black, Si Cl Lo
88-124: 10 YR 3/1 Very Dark Gray and some gley (Gley 2 6/10BG Greenish Gray) increasing with depth, Si Cl, hatch lines indicate peat fibers

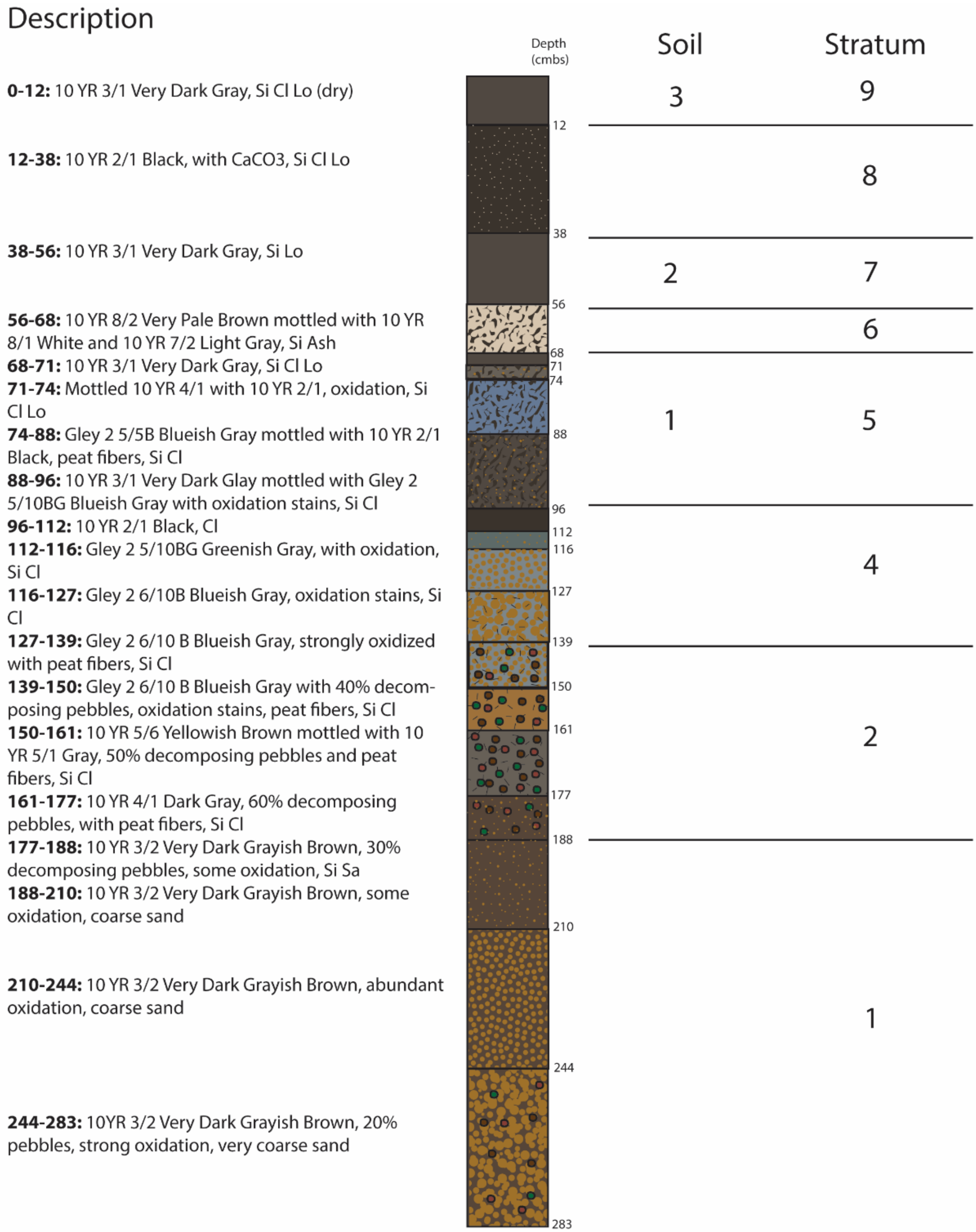
124-143: Gley 2 6/10 BG Blueish Gray with oxidation stains, Cl Lo

143-154: Gley 2 6/10 GB and 50 % decomposing pebbles, Si Cl

154-201: 10 YR 4/1 Dark Gray, becomes slightly lighter with depth and50% decomposing pebbles, Si Cl

201-222: 10 YR 4/1 Dark Gray, Gravely Sa with oxidation stains. Become better sorted with depth

Figure 12. Field observations for Auger 9.



Description

0-12: 10 YR 3/1 Very Dark Gray, Si Cl Lo (dry)

12-38: 10 YR 2/1 Black, with CaCO3, Si Cl Lo

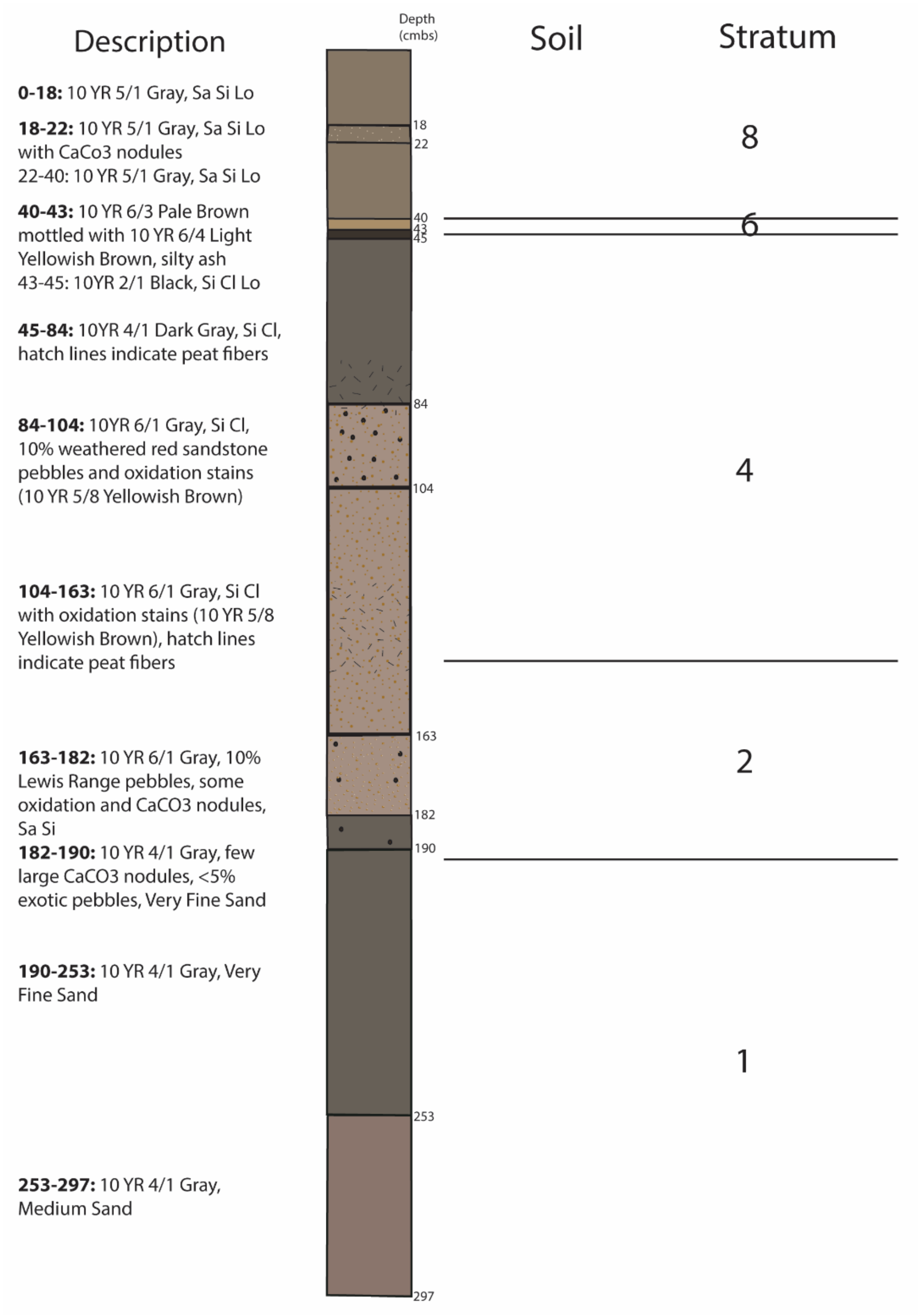
38-56: 10 YR 3/1 Very Dark Gray, Si Lo

56-68: 10 YR 8/2 Very Pale Brown mottled with 10 YR 8/1 White and 10 YR 7/2 Light Gray, Si Ash
68-71: 10 YR 3/1 Very Dark Gray, Si Cl Lo
71-74: Mottled 10 YR 4/1 with 10 YR 2/1, oxidation, Si Cl Lo
74-88: Gley 2 5/5B Blueish Gray mottled with 10 YR 2/1 Black, peat fibers, Si Cl
88-96: 10 YR 3/1 Very Dark Glay mottled with Gley 2 5/10BG Blueish Gray with oxidation stains, Si Cl
96-112: 10 YR 2/1 Black, Cl
112-116: Gley 2 5/10BG Greenish Gray, with oxidation, Si Cl
116-127: Gley 2 6/10B Blueish Gray, oxidation stains, Si Cl
127-139: Gley 2 6/10 B Blueish Gray, strongly oxidized with peat fibers, Si Cl
139-150: Gley 2 6/10 B Blueish Gray with 40% decomposing pebbles, oxidation stains, peat fibers, Si Cl
150-161: 10 YR 5/6 Yellowish Brown mottled with 10 YR 5/1 Gray, 50% decomposing pebbles and peat fibers, Si Cl
161-177: 10 YR 4/1 Dark Gray, 60% decomposing pebbles, with peat fibers, Si Cl
177-188: 10 YR 3/2 Very Dark Grayish Brown, 30% decomposing pebbles, some oxidation, Si Sa
188-210: 10 YR 3/2 Very Dark Grayish Brown, some oxidation, coarse sand

210-244: 10 YR 3/2 Very Dark Grayish Brown, abundant oxidation, coarse sand

244-283: 10YR 3/2 Very Dark Grayish Brown, 20% pebbles, strong oxidation, very coarse sand

Figure 13. Field observations on Auger 8.



Description

0-18: 10 YR 5/1 Gray, Sa Si Lo

18-22: 10 YR 5/1 Gray, Sa Si Lo with CaCo3 nodules
22-40: 10 YR 5/1 Gray, Sa Si Lo

40-43: 10 YR 6/3 Pale Brown mottled with 10 YR 6/4 Light Yellowish Brown, silty ash
43-45: 10YR 2/1 Black, Si Cl Lo

45-84: 10YR 4/1 Dark Gray, Si Cl, hatch lines indicate peat fibers

84-104: 10YR 6/1 Gray, Si Cl, 10% weathered red sandstone pebbles and oxidation stains (10 YR 5/8 Yellowish Brown)

104-163: 10 YR 6/1 Gray, Si Cl with oxidation stains (10 YR 5/8 Yellowish Brown), hatch lines indicate peat fibers

163-182: 10 YR 6/1 Gray, 10% Lewis Range pebbles, some oxidation and CaCO3 nodules, Sa Si
182-190: 10 YR 4/1 Gray, few large CaCO3 nodules, <5% exotic pebbles, Very Fine Sand

190-253: 10 YR 4/1 Gray, Very Fine Sand

253-297: 10 YR 4/1 Gray, Medium Sand

Figure 14. Field observations for Auger 2.

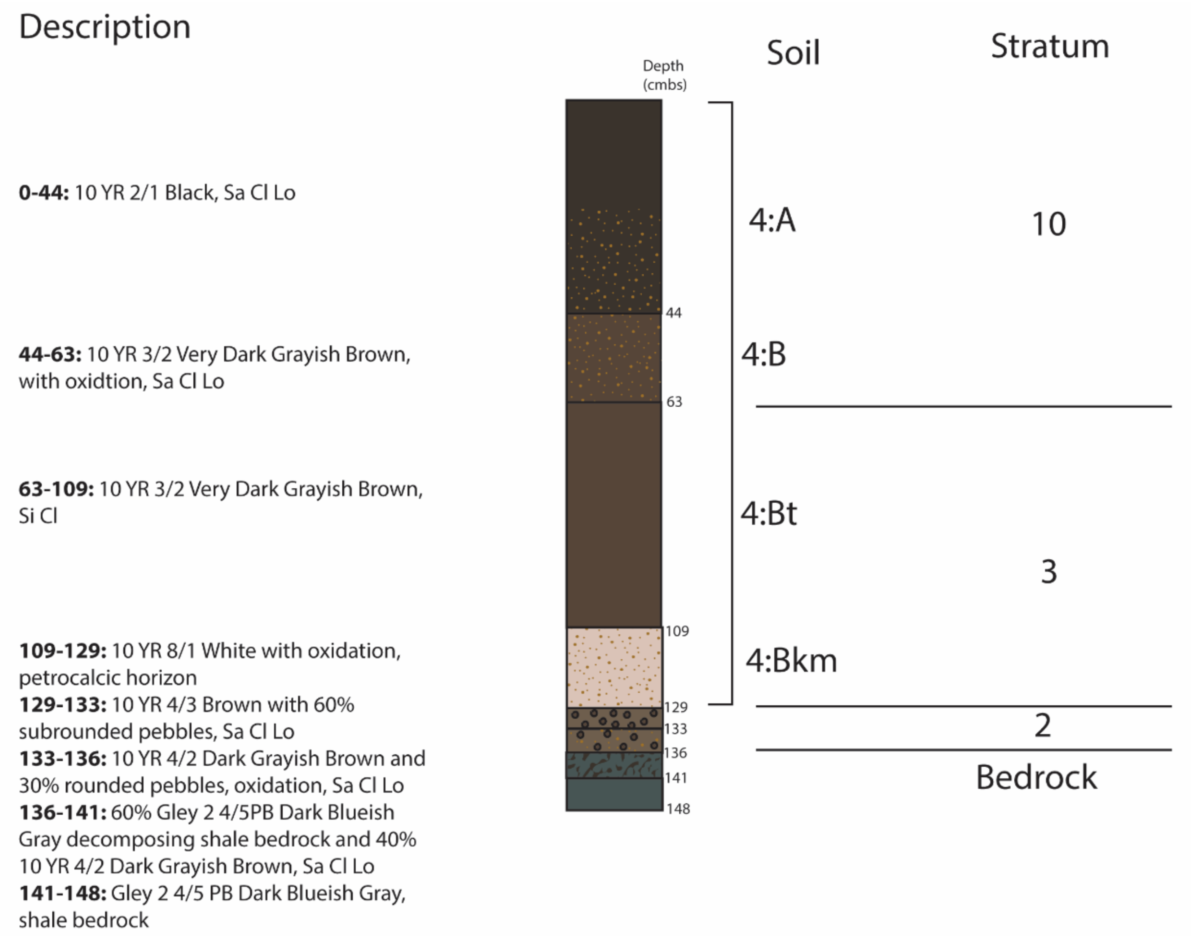


Figure 15. Field observations for Auger 6.

To bolster the basic stratigraphic interpretation, soil samples from the auger sediments were collected to analyze particle size, calcium carbonate, and organic matter content in the geoarchaeology lab at the University of Arizona (UA). Comparing the physical and chemical characteristics of the individual stratigraphic layers facilitated developing gross interpretations about the geological mechanisms that deposited and weathered the sediments. Throughout the process of digging the auger tests, representative subsamples (about two cups in volume) were collected from major stratigraphic units. Opportunistic samples were also collected when paleobotanical remains, organic rich sediments, or interesting sediment texture compositions were encountered. In total, 95 soil samples were collected from the auger tests. All samples were dried under the fume hood in the UA geoarchaeology lab.

Collection of Sediment, Charcoal, and Pollen Samples from Excavation Units

In the 2016 season, the research team excavated two 2m x 2m excavation units. These units were termed “Block 101” and “Block 301”. The units were located on the northwestern side of the pond at the site and separated by a linear distance of seven meters (Figure 10). During the course of the archaeological excavations, the excavators collected nine sediment and 18 charcoal samples from the features. All charcoal fragments that were potentially datable were collected, and at least one sediment sample was collected from each feature. A grab sample was also collected from each strata exposed in the walls of excavation block 101, which were used in this analysis. Sediment samples were not collected from block 301 because the stratigraphy was congruent between the units. To collect the pollen samples, a 10cm x 10cm bulk column in the southeast quadrant of excavation block 301 was collected in 2-cm levels (Figure 16). This column extended 42 cm below the block 301 datum.

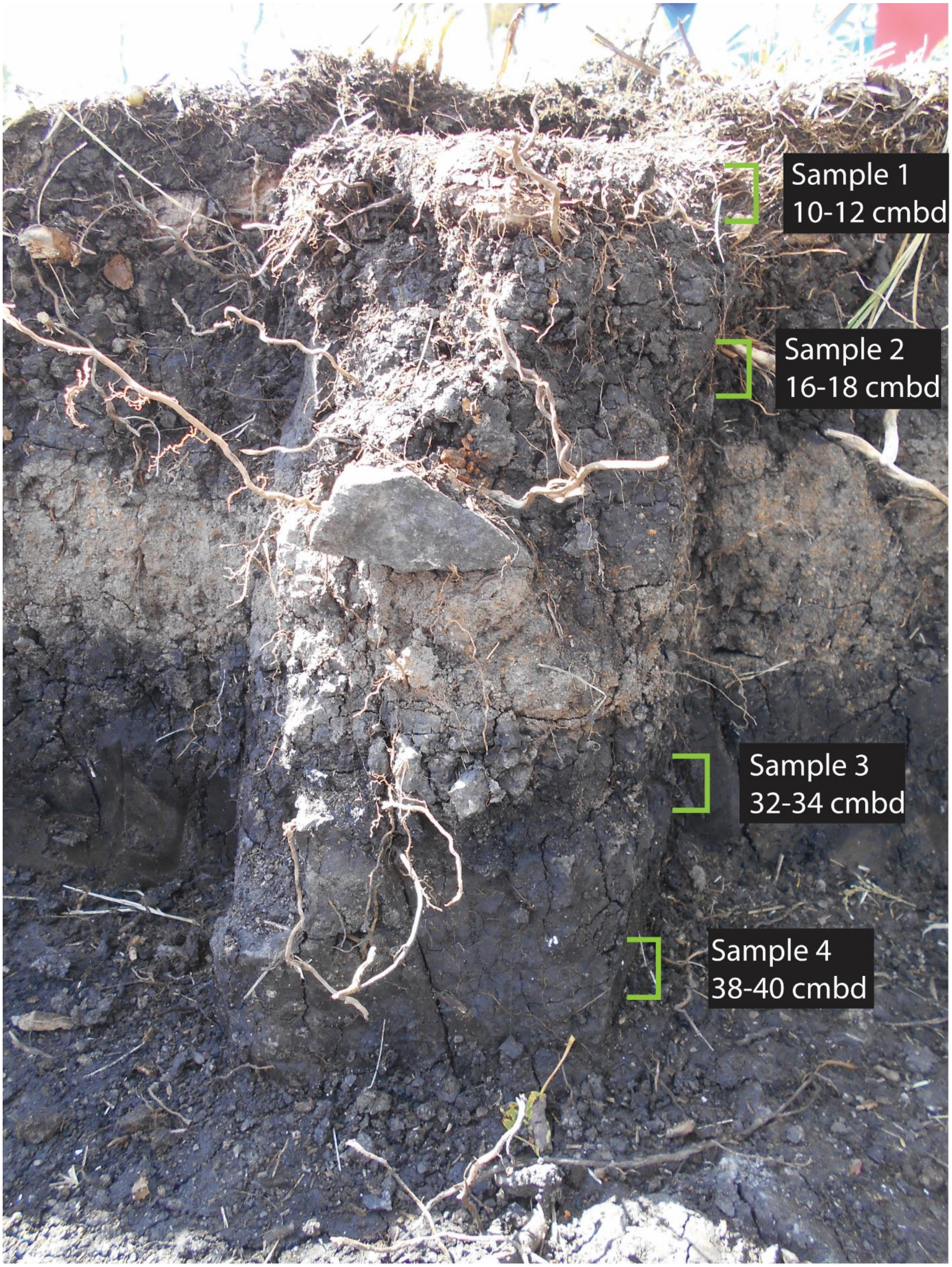


Figure 16. Pollen sample locations in block 301 bulk column sample.

Laboratory Soil Analysis

Particle Size Analysis

The particle size and sorting of different sedimentary matrixes provide important data in this study that are used to infer the transport mechanisms that deposited the sediment. For example, well sorted fine-grained deposits usually settle though suspension in slack water environments, whereas poorly sorted matrixes that are dominated with large angular cobbles are usually deposited by mass wasting events as a colluvial deposit.

Using the pipette method (Janitzky 1986a), 26 samples were run for particle size analysis (Table 1). To characterize the difference between the soils in the pond margin and the soils in the center of the pond basin, six samples were selected from Auger 2 (representing the pond center), 19 samples from Auger 9 (representing the pond margin), and one sample from Auger Test 8 (also on the pond margin). Because samples were opportunistically collected in the field, there was not an equal number of samples from each auger test. Due to this, the resolution of the particle size data for each auger profile is not the same, and is a source of bias in this work. For instance, Auger 8 has 19 particle size data points, but Auger 2 only has six. Drawing from these data, it is easier to see change in the depositional environments of Auger 8 than of Auger 2.

Using the pipette method entailed grinding each sample with a ceramic mortar and pestle until 25 grams of fine fraction sediment (clasts less than 2 mm in diameter) was produced. The remaining clasts with a diameter larger than 2 mm were weighted to calculate the gravel component in each sample. The fine fraction samples were treated with HCl to remove carbonates, then with hydrogen peroxide (30 percent solution) to remove the organic matter. The percentage of sand was found by wet sieving each sample to isolate the sand particles, which were then mechanically sieved into Wentworth size classes and weighed. To find the percentage of silt and clay, the remaining sediments were suspended in large cylinders with dispersant and the settling rates of silt and clay were used to calculate the total percentage of silts and clay in the original 25 g sample (Table 1). This data was graphed to make weight by depth diagrams for the soil profiles of Auger Tests 2 and 9 (Figures 17 and 18).

Table 1. Soil Laboratory Data.

						Texture without Gra			Texture With Gravel				Sand Breakdown						
Sample #	Depth (cmbd)	Lithostratigraphic Unit	Interpretation	Soil and Horizon	Texture	Sand %	Silt%	Clay %	Gravel %	Sand %	Silt%	Clay %	%VC	%C	%Med	%Fine	%VF	%OM	%CaCO3
Auger Test 9																			
110	6-10	9	Alluvial Overbank Deposits	3: A	Loam	48	38	15	12	42	33	13	20	21	20	22	17	9.59	0.14
111	14-19	9	Alluvial Overbank Deposits	3: E	Loam	28	45	27	3	28	44	26	7	12	21	33	29	2.63	1.73
113	34-40	9	Alluvial Overbank Deposits	3: Bt2	Clay loam	29	39	31	0	29	39	31	3	15	31	27	25	3.1	0.25
114	43-49	9	Alluvial Overbank Deposits	3: Bk	Loam	47	38	15	3	46	37	14	1	28	34	22	15	1.44	0.14
119	56-64	8	Pond Clay		Clay	15	36	49	0	15	36	49	0	15	27	32	27	1.12	0
120	62-69	7	Eolian and Overland Flow	2: A	Clay	37	18	46	0	37	18	46	0	18	33	29	21	1.05	0.21
115	66-71	7	Anthropogenic Organic Len	2: A	Sandy clay	61	2	37	0	61	2	37	0	11	33	34	22	3	1.58
116	75-80	6	Weathered Mazama Tephra		Clay loam	34	35	31	0	34	35	31	1	19	33	26	21	0.98	0.63
117	72-79	6	Mazama Tephra		Loam	34	52	14	0	34	52	14	1	11	24	31	33	1.54	0.47
118	78-82	6	Mazama Tephra		Silt loam	25	69	6	0	25	69	6	2	9	19	24	46	1.66	0.14
91	84-99	5	Eolian and Overland Flow	1: A	Loam	46	39	15	11	41	35	14	1	18	34	28	20	2.35	1.13
93	114-124	4	Pond Clay	1: A	Clay loam	18	44	39	0	18	44	39	0	12	15	33	39	0.8	0.09
94	124-129	4	Pond Clay		Clay	14	18	68	0	14	18	68	0	0	9	38	53	1.15	0.32
95	135-143	4	Pond Clay		Silty clay	12	45	42	0	12	45	42	0	0	9	39	52	0.92	0.6
96	143-148	2	Glacial Outwash		Very Pebbly Clay	29	19	52	36	18	12	34	3	8	27	31	31	0.61	0.2
97	154-160	2	Glacial Outwash		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6	10	21	35	28	0.84	0.13
98	160-172	2	Glacial Outwash		Very Pebbly Loam	39	48	13	40	23	29	8	11	16	20	29	24	0.59	0.44
99	172-185	2	Glacial Outwash		Very Pebbly Sandy loam	52	35	13	43	29	20	8	23	23	21	19	15	0.65	0.97
100	201-219	2	Glacial Outwash		Very Pebbly Loam	49	37	14	50	24	19	7	20	21	20	22	17	0.41	0.12
101	219-222	2	Glacial Outwash		Very Pebbly Sandy loam	63	22	15	35	41	14	10	9	10	14	37	30	0.7	N/A
Auger Test 2																			
1	20.0	8	Pond Clay		Clay	12	24	64	0	12	24	63	27	23	14	18	18	2.74	16.26
4	80-85	4	Pond Clay		Pebbly Clay	1	0	100	23	0	0	77	0	1	0	0	0	0.88	18.13
6	120-125	4	Pond Clay		Pebbly Clay loam	19	43	39	27	14	31	28	0	3	9	31	57	0.72	11.05
7	145-150	2	Glacial Outwash		Very Pebbly Clay loam	27	39	34	45	15	22	19	4	5	12	32	47	0.75	10.93
8	170-178	2	Glacial Outwash		Very Pebbly Silt loam	30	56	15	38	18	35	9	3	5	9	29	54	0.75	3.15
9	182-188	2	Glacial Outwash		Very Pebbly Clay	32	20	48	36	21	13	31	3	5	9	29	54	1.12	2.29
Auger Test 8																			
78	244-283	1	Glacial Till		Pebbly Sandy loam	66	20	14	18	54	17	12	16	25	22	24	14	0.61	0.14

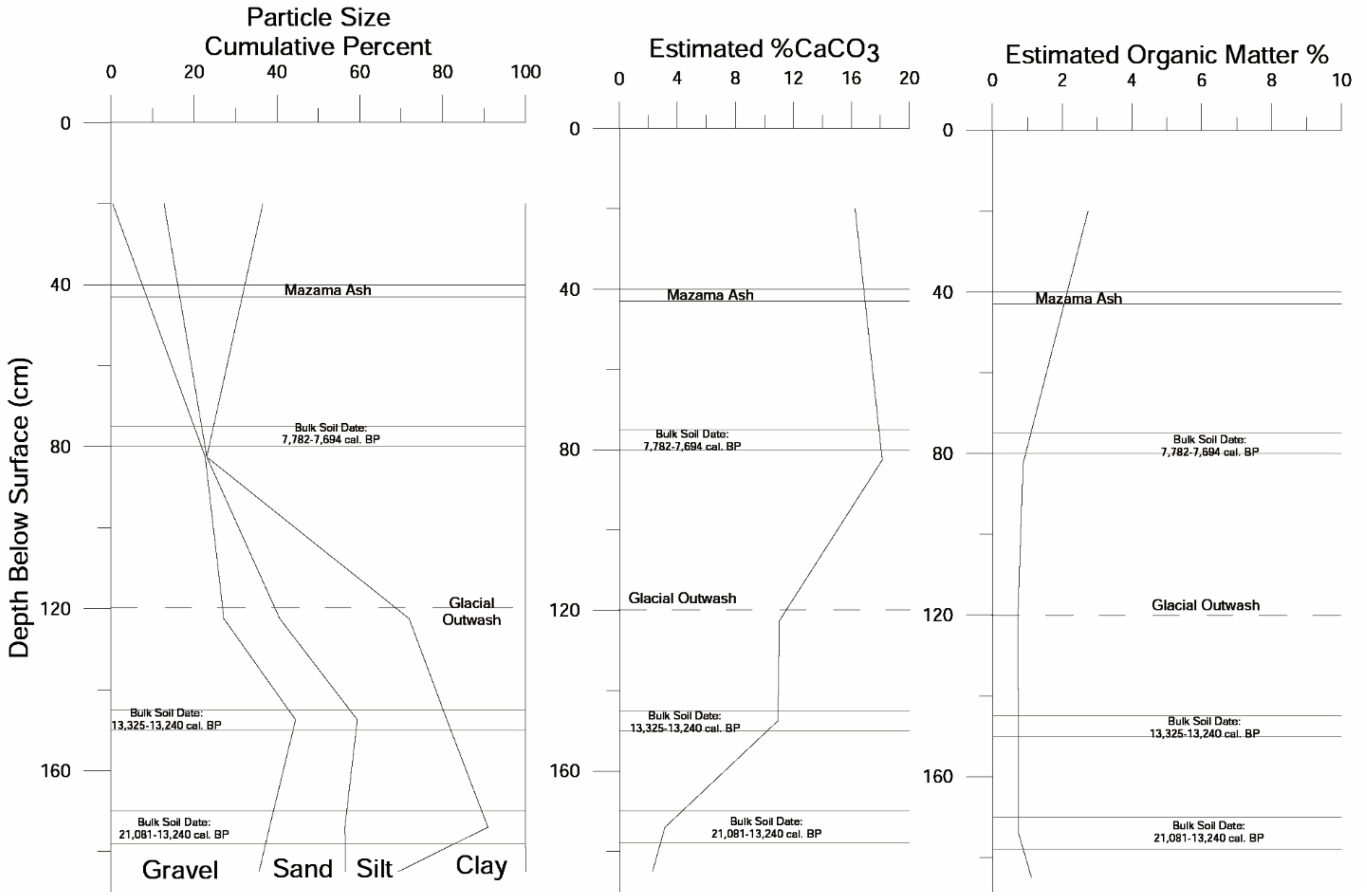


Figure 17. Soil laboratory data for auger test 2.

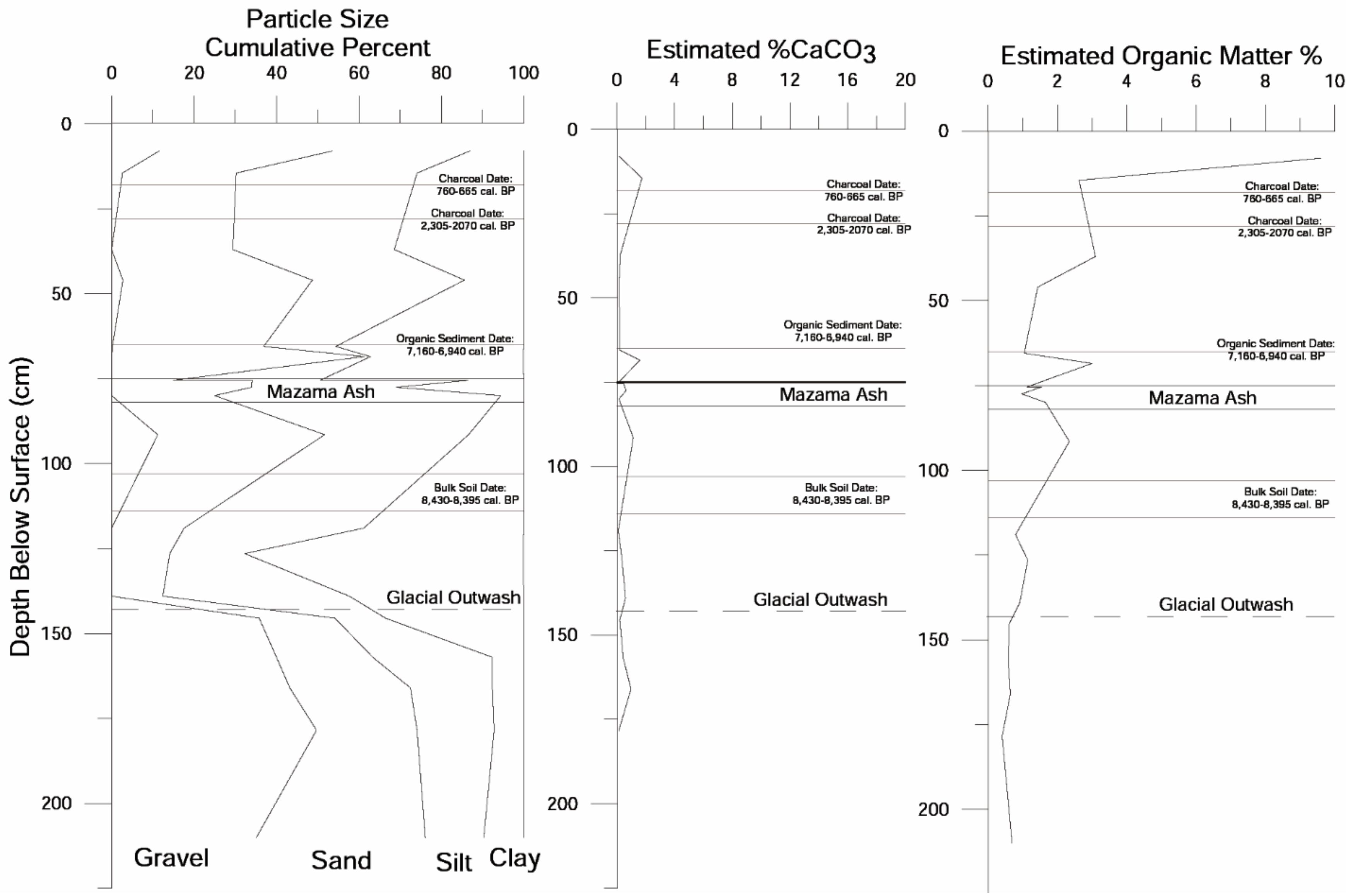


Figure 18. Soil laboratory analysis for auger 9

Pedogenic Carbonate

The percentage of calcium carbonate is a standard soil science method of differentiating strata and understanding the landscape evolution a soil profile has experienced. For example, a peak in the %$CaCO_3$ deep in the soil indicates that the soil has been stable for a long time. This is because $CaCO_3$ is mobile in suspension, and is transported and deposited with soil moisture flow. A bump in $CaCO_3$ at depth indicates that the soil has been sitting on the landscape for a long time to allow such an accumulation of $CaCO_3$ to form.

Twenty-six samples were measured for pedogenic carbonate content using the Chittick method (Machette 1986). Only the fine fraction is used in this test. These samples were reacted with 6 N HCl in the Chittick apparatus to measure the amount of gas the reaction produced. The amount of gas was then calibrated with the temperature and pressure of the air in the lab to calculate the percentage of $CaCO_3$ in each sample (Table 1). These data were mapped by depth for Auger Tests 2 and 9 (Figures 17 and 18).

Soil Organic Matter

Testing organic matter is a good way to locate buried soil horizons. This is because the surface of a soil always contains the most OM in the entire profile. If a soil is quickly buried, this spike in OM should be preserved under the overlying sediment. The organic matter content of 28 samples was measured using the Walkley-Black method (Allison 1965 and Janitzky 1986b). The principal of the Walkley-Black method is to use 20 mg of sulfuric acid and 10 mg of potassium dichromate to remove the organic matter in the sample. After letting the sample react for 30 minutes, sulfuric dichromate was titrated into the reacted samples until all of the organic matter was removed. The amounts of these chemicals used to react the samples were then used to calculate the original amount of organic matter in each sample (Table 1). These data were mapped by depth for Auger Tests 2 and 9 (Figures 17 and 18).

Radiocarbon Dating

Our project budget allowed for nine radiocarbon dates (Table 2). These numerical dates were important for placing lithostratigraphic units into a regional context. Three samples (two charcoal and one charred sediment) from the cultural occupations were dated by Beta Analytic. Six bulk sediment samples from the auger tests were dated at the University of Arizona AMS lab to date the geomorphic evolution of the site. Beta Analytic pretreated the two charcoal samples with the standard acid/alkali/acid pretreatment and the one organic sediment sample with acid washes. The author pretreated the six bulk sediment samples in the geoarchaeology lab with the standard acid/alkali/acid pretreatment.

Pollen Analysis

Pollen is a good way to understand the paleoenvironment at both the regional and local scales. The pollen samples were collected from one of the 2016 University of Arizona excavation units (Unit 301), not from the auger tests that are the basis of this geoarchaeological analysis. Unit 301 lies about 10 meters northwest of Auger 9 (Figure 10). The stratigraphy from this excavation unit is continuous with the stratigraphy in the auger tests, so the pollen data can be extrapolated to the lager geomorphic picture. Since pollen analysis is a costly procedure, I elected to run a pilot study on the samples to find if any pollen was preserved, before committing to have all of the samples counted. For the pilot study, four samples were selected from the bulk column in excavation unit 301 at 10—12, 16—18, 32—34 and 38—40 cm below datum (Figure 16). Susan Smith (paleoecologist) was contracted to count these samples. She had the pollen grains isolated from their sediment matrix by the Texas A&M Laboratory of Paleoecology, and then counted the grains underneath a microscope (Table 3) (Smith 2017).

Data Management

All data (including field notes) associated with this project will be stored on the University of Arizona S: Drive under the ‘Billy Big Spring Archaeology Project’ folder. The remaining soil samples will be stored in the University of Arizona Bureau of Applied Research in Anthropology (BARA) lab in the Emile Haury Building, room 316.

Table 2. Radiocarbon dates from BBSs.

Lab Sample ID	**Material**	**Loci**	**Pretr-eatm-ent**	**Lab**	**Conventional Radiocarbon Age**	**2 Sigma Calibration (cal. BP)**	**Mean Cal. Age**
Beta-446257 : ZEDENO 2016-1	Charred material	Block 100; PD 119, Artifact# 21; 18 cmbd, Stratum 9; E horizon	acid/ alkali/ acid	Beta Analytic	780 +/- 40	760—665	~710
Beta-446258 : ZEDENO 2016-2	Charred material	Block 100; PD 129; Artifact 138; 28 cmbd; Stratum 9; Bt1 horizon	acid/ alkali/ acid	Beta Analytic	2170 +/- 30	2306—2225; 2204—2115; 2205—2115; 2075—2070; 2075—2070	~2,210
Beta-446259 : ZEDENO 2016-3	Organic sediment	Block 100; PD 152; Artifact 195; 70 cmbd; Stratum 7; Soil 2	Acid washes	Beta Analytic	6130 +/- 30	7160—6940	~7,030
B10568	Soil Humin	Auger 9 (inside block 101) 103—114 cmbs; Stratum 5; Soil 1	acid/ alkali/ acid	UA AMS	7635 +/- 25	8430—8395	~8,415
B10573A	Soil Humin	Auger 8; 92—96 cmbs; Stratum 5; Soil 1	acid/ alkali/ acid	UA AMS	5,779 +/- 22	6636—6555	~6,590
B10571	Soil Humin	Auger 8; 127—139 cmbs; Stratum 4	acid/ alkali/ acid	UA AMS	12082 +/-51	14017—13831	~13,920
B10572R	Soil Humin	Auger 2; 75—80 cmbs; Stratum 4	acid/ alkali/ acid	UA AMS	6915 +/- 25	7782—7694	~7,730
B10570	Soil Humin	Auger 2; 145—150 cmbs; Stratum 2	acid/ alkali/ acid	US AMS	11440 +/- 33	13325—13240	~13,290
B10569	Soil Humin	Auger 2; 170—178 cmbs; Stratum 2	acid/ alkali/ acid	UA AMS	17375 +/- 70	21081—20832	~20,950

Table 3. Pollen results from Unit 301 (Smith 2017). Sample 136 had so little pollen that no percentage was calculated for the individual species represented. The charcoal matrix shows the amount of sediment in the sample that was composed of charcoal fragments.

Geo Sample #		122		125		133		136
Depth (cmbd)		10—12		16—18		32—34		38—40
Stratum		I		II		IV		V
Tracers (initial concentration 20,848 Lycopodium spores)		104		215		296		91
Pollen Sum		323		316		104		13
Pollen Concentration gr/gm (sample weights 10 grams)		6474.9		3064.2		732.5		297.8
Taxon Richness		17		18		10		4
Taxon Name	**Common Name**	**Counts**	**%**	**Counts**	**%**	**Counts**	**%**	**Counts**
Picea	Spruce	1	0.3	1	0.3			
Abies	Fir	8	2.5	9	2.8	4	3.8	
Large Pine poss. Pinus contorta	poss. Lodgepole Pine	196	60.7	144	45.6	57	54.8	7
Small Pine	Other Pines	9	2.8	26	8.2	9	8.7	
Cupressaceae	Juniper	1	0.3	8	2.5			2
Populus	Aspen	4	1.2	3	0.9	4	3.8	
Rosaceae	Rose Family	1	0.3					
Artemisia	Sagebrush	3	0.9	7	2.2	1	1.0	
Cheno-am	Cheno-am	1	0.3	7	2.2	4	3.8	
Asteraceae	Sunflower Family	4	1.2	14	4.4	7	6.7	
Liguliflorae	Chicory Tribe	11	3.4	4	1.3			
Poaceae	Grass Family	12	3.7	10	3.2	2	1.9	
Large Poaceae	Large Grass type	5	1.5	3	0.9	1	1.0	
Plantago	Indian wheat	1	0.3					
Caryophyllaceae	Pink Family			1	0.3	1	1.0	
Scrophulariaceae	Penstemon Family			1	0.3			
Liliaceae	Lily Family			1	0.3			
Apiaceae	Carrot Family	1	0.3	2	0.6			
Salix	Willow			2	0.6			
Alnus	Alder	2	0.6	3	0.9			
Betula	Birch	2	0.6					
Cyperaceae	Sedge	52	16.1	36	11.4	6	5.8	3
Degraded		9	2.8	32	10.1	8	7.7	1
Unknowns				2	0.6			
Non-Pollen Forms								
Trilete Spore		2		1		1		
Monolete Spore		1						
Charcoal Matrix						20%		20%

CHAPTER 4: RESULTS

From field observations and laboratory analyses, ten major lithostratigraphic strata (1—10, oldest to youngest, each identified as “Stratum”) and four soils (1—4, oldest to youngest, each identified as “Soil”) were identified (Figure 19). The strata will be described in order of age, starting with the lowest, oldest layer, and then proceeding up the profile to the highest, youngest layer, addressing the soils in stratigraphic sequence.

Bedrock

The bottom of Auger 6 reached the underlying bedrock, which is part of the Blackleaf Formation composed of mudstone interbedded with layers of sandstone (Cannon 1996b).

Stratum 1

The oldest Stratum is composed of a pebbly sandy loam. The sediment matrix is sand dominated, poorly sorted, and has massive bedding. These characteristics are diagnostic of glacial till. The matrix of this deposit contains large proportions of red and green argillite from the Belt Supergroup formation in the Rocky Mountains to the west, which is congruent with Karlstrom’s observations about Rocky Mountain alpine glacier tills in this region. He found these tills to usually be composed of 40 to 50 percent Belt Supergroup sedimentary rocks in a sandy loam matrix (Karlstrom 2000:180—181). This stratum extends from about two meters below the surface downwards. The deepest auger test reached a depth of 297 cm below the surface and was terminated because the equipment could not reach any further. This stratum likely extends deeper past this depth.

There was no organic material from this Stratum for a radiocarbon date, but the unit above (Stratum 2) returned two bulk soil radiocarbon dates (B10570 and B10569) (Table 2). Stratum 2 is at least ~20,950 cal. yrs. BP (discussed below), therefore Stratum 1 must be older, and likely dates to the Pinedale 2 or 1 glaciations (the maximums occurred at 23,860—22,900 cal. yrs. BP and 26,160—25,700 cal. yrs. BP, respectively; Fullerton et al. 2004:10—12).

Stratum 2

This Stratum consists of interbedded sediments ranging from very pebbly sandy loams to very pebbly clays. This large range of clast sizes and the presence of a few large cobbles is also indicative of a glacial source. This Stratum is composed of many layers of sediments that follow a fining-upwards sequence. The lowest layer has the highest percentage of sand with some silt. Higher in the stratum, the percentage of sand decreases and is replaced with silt as the dominant textural class (Table 1). The amount of gravel stays constant throughout this Stratum, and clay remains a minor constituent until the very top of the layer. Fining-upwards sequences signify alluvial deposition with decreasing stream flow overtime (Waters 1992:133). A decrease in stream flow is usually interpreted as showing channel migration across a landscape, with the larger clasts composing the old stream channel and the finer silt and clay particles composing point bars. The mix of grain sizes present in this layer indicate that the origin of this sediment was glacial, and the pattern of deposition shows that they were laid down by moving water. Considering these data, this layer is likely glacial outwash that was deposited by moving streams of glacial melt water. This Stratum represents the post-glacial environment when there was much surface water on the landscape from melting glaciers. There would have been large piles of unconsolidated glacial sediments prone to episodes of mass wasting on this landscape. On this rapidly changing landscape, large amounts of sediments were being reworked by the forces of water and gravity. At the end of this time, glacial outwash had shaped the basin at this site.

The two bulk sediment radiocarbon dates from this Stratum support the interpretation that it originated from melting Wisconsin-age glaciers. Both were taken from the center of the pond basin (Auger Test 2). One originates from 170 to 178 cm below surface and dates to ~20,950 cal. yr. BP (B10569 [Table 2]), the other is from 145 to 150 cm below surface, and dates to ~13,290 cal. yr. BP (B10570). Relatively, the Pinedale 3 maximum occurred after 22,900 cal. yrs. BP but before 17,640—17,520 cal. yrs. BP (Fullerton et al. 2004:11). Between the Pinedale 2 and 3 maxima, the Two Medicine Lobe retreated a great distance (likely back to Marias Pass) (Fullerton et al. 2004:10). Considering this, the ~20,950 cal. yr. BP date should represent a time when the landscape was subaerially exposed between the Pinedale 2 and 3 maxima, meaning that this outwash layer originated from the Pinedale 3 glaciation. The ~13,290 cal. yr. BP date represents a point after the Two Medicine lobe had already retreated up into Marias Pass and till was experiencing episodes of mass wasting across the recently deglaciated landscape.

Stratum 3

This Stratum consists of a layer of silty clay loam with massive bedding on the eastern side of the pond basin. The silty texture of this layer indicates that it may also have glacial origins as loess. This is a speculative interpretation, since no large loess deposits have been mapped in this region of Montana. This Stratum was only encountered in one auger test, so perhaps it is a fairly localized phenomenon. There are no radiocarbon dates from this Stratum to test this hypothesis. If not glacial loess, it could have originated as a more recent aeolian deposit.

Stratum 4

Stratum 4 is a silty clay that contains no gravels, was heavily gleyed (Figures 12 and 13), and only existed within the bottom of the basin. Gleying occurs post depositionally when a perched water table sits on top of an impermeable sedimentary layer, and causes the underlying sediment to become anoxic, causing it to turn blue/gray in color. Fine sediments like this silty clay need to be deposited in a low-energy environment, and settling from suspension in standing water is one potential process. Stratum 4 is likely a pond deposit because: 1) it was deposited within a basin, 2) it has a fine-grained texture, and 3) it has a heavily gleyed color. Sediments would have entered the pond system either by moving with surface water or as eolian dust that settled on the water's surface (Waters 1992:222; Feibel 2001:135).

Initially, Stratum 4 was deposited throughout the entire basin, but eventually retreated to only being deposited in the basin center. One bulk soil radiocarbon date (B10571) at the base of this layer shows that deposition began by ~13,920 cal. yrs. BP. Deposition ended on the basin margin sometime before ~8,415 cal. yrs. BP (B10568), whereas in the basin center, sedimentation continued until after ~7,730 cal. BP (B10572R). B10573A is stratigraphically lower than the Mazama ash (Stratum 6), but the radiocarbon date post-dates the eruption. This radiocarbon date is disregarded in this study. In all, these dates show that the Stratum 4 lacustrine depositional regime was reduced in area over time.

Stratum 5

After the pond water retreated in extent, Stratum 5 was deposited on the exposed basin margin. This deposit has a loamy texture with three times as much sand as Stratum 4, and a high percentage of silt. Sand and silt can be entrained by the overland flow of water and also by wind (Waters 1992). The Great Plains are notoriously windy and dusty (Holliday 1987), so eolian transport likely played a role in delivering the sediments in Stratum 5. Eolian sediments are typically well-sorted (Water 1992:187), but can also exist as poorly sorted deposits if wind speeds and durations are variable. This Stratum is likely mostly composed of eolian sediments with the addition of some sediment from overland flow. One bulk soil radiocarbon date from this Stratum (B10568), shows that deposition of this layer began before ~8,415 cal. yrs. BP.

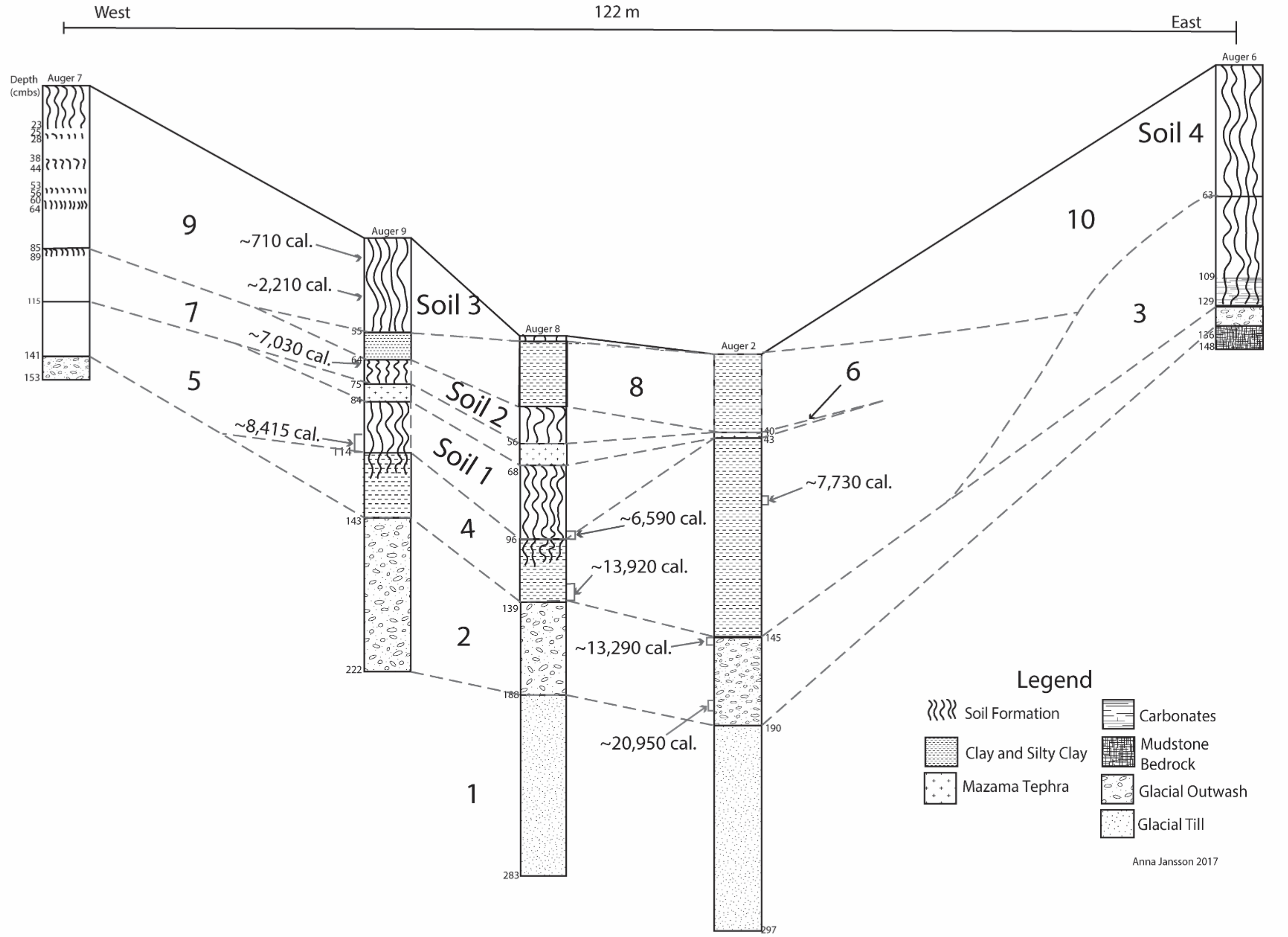


Figure 19. Fence diagram of auger tests. 20X vertical exaggeration. Numbers represent strata.

Soil 1

This is the oldest soil in the stratigraphic sequence at this site. This soil spans Strata 4 and 5. Soil 1 began forming in Stratum 4 after the retreat the pond water, and then continued to form as the sediments in Stratum 5 were deposited on top of the soil surface. When pedogenesis keeps pace with sedimentation, the result is called “upbuilding,” “overthickening,” or “cumulization” of the soil (Holliday 2004:91). This soil displays classic soil trends in $CaCO_3$ and organic matter content (high percentages near the soil surface that decline with depth) (Figure 18). This soil and Stratum 5 is buried by Stratum 6, which is tephra from the eruption of Mount Mazama (~7,633 cal. yr. BP (Egan et al. 2015)). The change from pond deposition to soil formation suggests drying and prolonged exposure of the surface, which is also supported by the radiocarbon dates.

Stratum 6

This lithostratigraphic unit is tephra from the eruption of Mount Mazama, which occurred ~7,633 cal. yr. BP and covered much of the northwestern United States (Egan et al. 2015). Under a microscope, Andrea Freeman identified volcanic glass shards with elongated bubbles in a sample from this stratum, proving that this stratum is a volcanic ash fall (Andrea Freeman, personal communication 2016). The radiocarbon data above this layer in Stratum 7 (Beta 446259 : ZEDENO 2016-3) places this layer in the correct time range have originated from the ~7,633 eruption of Mount Mazama. Ash fall from this eruption was only preserved within the pond basin, and varies in thickness between three and seven cm. The subtle shape of the basin is expressed by the way the ash drapes across the paleolandscape of the pond basin.

Stratum 7

The sediments deposited on top of the tephra layer compose Stratum 7. These sediments are mostly composed of clay, but also contain a moderate amount of sand (Table 1). Like

Stratum 5, these sediments likely originated via a combination of overland flow and eolian input. A cultural occupation occurred while these sediments were accumulating and left small lenses of organic rich sediment and charcoal throughout this layer. One of these lenses of organic sediment near the top of the stratum was radiocarbon dated at ~7,030 cal. yrs. BP (Beta-446259 : ZEDENO 2016-3).

Soil 2

A soil formed in the sediments of Stratum 7. It has a dark gray color (Figures 11, 12, and 13) and is mottled with some black organic rick pockets, and lightly oxidized throughout. This soil was wet when excavated, so it did not exhibit clear soil structure. There is a substantial increase in the organic matter content within this horizon, supporting the interpretation that this is a buried soil (Figure 18). While this soil was forming on the basin margin, clay deposition (Strata 4 and 8) continued in the basin center, indicating that there was still water in the basin center.

Stratum 8

Stratum 8 represents the expansion of the clay depositional regime across the basin, reaching the margins. This clay contains a minor amount of silt and even less sand (Table 1). Like Stratum 4, the small particle size of this matrix and its location within a basin indicate that it was deposited by pond water. The readvance of water across the landscape indicates either an increase in precipitation and/or a decrease in temperature, which allowed the wetlands to expand across the basin.

Stratum 9

Stratum 9 is composed of a series of layers of clay loam interbedded with loam. A small stream flows less than 50 meters west of the basin at this site, and likely deposited the clay loam layers as overbank flooding deposits. A horizons (Soil 3) formed in these deposits during times of non-deposition. These alluvial overbank layers are most clearly expressed in auger test 7, which is the nearest test to the stream. Due to its proximity, this locality received the largest amounts of sentiments, hence separating the individual layers more clearly than the expression of Stratum 9 inside the basin. Pedogenesis has obscured these layer, with increasing effect further from the source of the sediment, typical of floodplain soils (Holliday 2004).

Soil 3

Soil 3 formed in Stratum 9, and represents the modern surface soil. On the western end of this auger transect, large alluvial over bank deposits have precluded continuous soil formation. The basin center has received less of this sediment input, so a continuous soil profile has formed with A, E, Bt and, Bk horizons (Figure 20). The presence of an argillic horizon (Bt) indicates that the associated modern geomorphic surface has been stable for some time. Argillic horizons form relatively slowing, generally requiring 3,000 to 5,000 years to form (Schaetzl and Anderson 2005:568). The organic matter content is very high near the surface, which is normal for the organic-rich Mollisol soils in this area (Haigh 1980) but may also be due to its wetland setting and the higher biological activity.

In a seemingly contradictory situation, both a calcic horizon (Bk) and an E horizon have formed in this soil. Calcic horizons are formed when $CaCO_3$ is dissolved and translocated downwards in suspension and then stops moving in the soil profile due to lack of energy (there is no more water to further translocation downward) (Schaetzl and Anderson 2005). In contrast, “podzolization" forms E horizons, where organic carbon, iron and/or aluminum are translocated from the upper profile to an illuvial horizon. Podzolization generally occurs in cool, humid climates where there is an excess of precipitation over evapotranspiration, such that water frequently moves completely throughout the profile (Schaetzl and Anderson 2005:440). Podzolization is best expressed under vegetation that produces acidic litter, such as coniferous forests and heather which aids in mobilizing the ions. The environment needed for a calcic horizon requires little water in a weakly acidic system, whereas podzolization requires abundant of water and a strongly acidic environment. The presence of these two horizons in this profile could be explained if the circumstances are that an acidic environment and large amounts of water are causing organic matter, iron, and aluminum to be leached from the upper profile and carried down to the level of the calcic horizon. Here, the water comes in contact with Stratum 8, which is a clay with 49.4% clay, 35.7% silt, and 14.9% sand. This clay-rich layer has low porosity, and acts as an aquiclude. Water perched at this location precipitates its carbonate as a Bk horizon, and flows laterally until it reaches past the extent of Stratum 8, and is again allowed to flow downward in the soil profile.

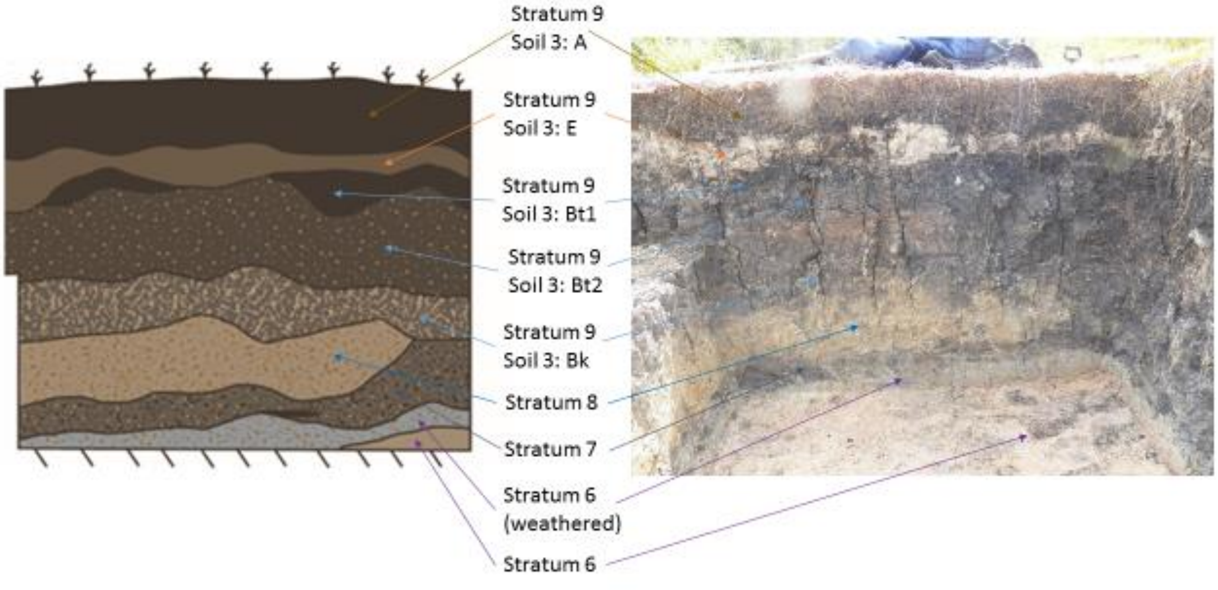


Figure 20. Excavation block 101 south wall stratigraphy showing Units 6, 7, 8, and 9 and Soil 3.

Stratum 10

This stratum is a sandy clay loam deposited on the eastern side of the pond basin. There were no clasts larger than pebbles in this stratum. To the east of the pond basin, a ridge steeply rises. This layer likely accumulated from downward creep of the upslope sediments, and from eolian transport. This layer sits directly upon Stratum 3, which likely dates to post-glacial times. This stratigraphic positioning suggests that Stratum 10 has been accumulating since the early-Holocene.

Soil 4

Within Strata 10 and 3, a soil profile containing an A, B, Bt, and Bkm horizon has formed. Petrocalcic horizons (Bkm) are horizons with cemented secondary carbonates (Schaetzl and Anderson 2005:118). Given the generally low levels of calcium carbonate in the pond deposits, dust is likely the source of these calcium carbonates (Holliday 1987). Petrocalcic horizons usually from slowly (Schaetzl and Anderson 2005:570), indicating that this geomorphic surface has remained stable for a long time.

Pollen Preservation

All of the pollen samples originated from Stratum 9, within Soil 3. Unfortunately, after counting the pollen in the samples, Dr. Smith found that the pollen at this site is heavily degraded. Beneath 38 cm, the grains had decomposed so much that the lowest sample was sterile for pollen (Smith 2017). She explained that the most likely reasons for pollen degradation are repetitive cycles of wetting and drying (Holloway 1989), basic (high pH) environments (Dimbleby 1957), and certain species of soil fungi and bacteria (Goldstein 1960).

The pollen grains were found within the matrix of Soil 3, but likely originate from the deposition of the parent material of the soil (Stratum 9) rather than the formation of the soil. In the pollen that was preserved, Smith saw evidence for regional climate change between the two highest samples. In Sample 1 (10–12 cm below datum [cmbd]), she finds 61 percent lodgepole pollen, but in Sample 2 (16—18 cmbd) lodgepole pollen decreases to only 46 percent along with a decrease in sedge (*Cyperaceae*), whereas the frequencies of the sunflower family, Cheno-am, small pine, juniper, sagebrush, and a variety of herbs and forbs increase (Table 3). The third deepest sample has increasing deterioration, but shares similar characteristics as Sample 2. Smith concludes that Sample 2 represents a drier environment with less tree cover than the younger Sample 1. The wetting trend to the present may reflect historic fire suppression, or a climatically wetter interval (Smith 2017). Despite the pollen being largely gone in the lower two strata, Smith saw microscopic charcoal particles in these samples (32—34 cmbd and 38—40 cmbd), which may reflect the occurrence of natural and frequent fires that maintained more open forest conditions that allowed a greater variety of herbs and forbs to flourish (Smith 2017).

Cultural Occupations

Dr. Zedeño’s excavations uncovered a wealth of cultural material at this site (Figure 21). To address human interaction with the Altithermal (10,625—6,850 cal. yrs. BP), the occupation dated to this period is the focus of this analysis, although more recent occupations are acknowledged.

Bones and Charred Sediment

The oldest occupation is situated within Stratum 7. This occupation contains one chert scrapping tool, many broken bones, and much charred sediment. Within Stratum 7 there are 1—2 cm thick lenses of organic-rich sandy clay, likely resulting from animal processing. This occupation overlies and thus postdates Stratum 6 (Mount Mazama tephra). One radiocarbon date on a lens of charred sediment dates this occupation to ~7,030 cal. yrs. BP. Significantly, this date falls within Cathy Barnosky's (1989) date for the Altithermal on the Northern Plains 10,625—6,850 cal. yrs. BP (9,400—6,000 ^{14}C yrs. BP), as well as a period of reduced water resources at this site (indicating increased aridity). The stratigraphy of the BBSs also indicates a period of increased aridity during a period with a similar timespan.

Later Occupations

There are at least four occupations on the pond margin within Stratum 9. Each of these occupations contained projectile points, flakes, faunal bone and fire cracked rock features. In this brief discussion, they will be referenced by the diagnostic projectile points they contain. The earliest occupation has McKean projectile points (Middle Archaic: ~4,771 to ~3,777 cal. yrs. BP (4,200 to 3,500 ^{14}C yrs. BP; Peck 2011). Above this is a Mid-to-Late Archaic occupation containing a Yonkee point and one reworked Besant. Yonkee points are one variant of the McKean Complex (Foor 1985) and date to roughly ~3,312 to ~2,340 cal. yrs. BP (3,100 to 2,300 ^{14}C yrs. BP in Wyoming archaeological sites (Kornfeld et al. 2010:125)). It is likely that Yonkee points in Montana are slightly later than the Wyoming finds. Besant points date to ~2,056 to ~1,385 cal. yrs. BP (2,100 to 1,500 ^{14}C yrs. BP (Peck 2011)). A radiocarbon sample (Beta-446258 : ZEDENO 2016-2) dates a piece of charcoal in this occupation to ~2,210 cal. yrs. BP. Next, there was an Avonlea occupation (Late Precontact: ~1,290 to ~1,010 cal. yrs. BP (1,350 to 1,100 ^{14}C yrs. BP (Peck 2011))), which was followed by an Old Women's phase occupation (Late Precontact: ~1,010 to ~300 cal. yrs. BP (1,100 to 250 ^{14}C yrs. BP (Peck 2011))).

Surface Finds

In the 2016 season 241 Early Archaic to Late Precontact artifacts were found scattered across the basin center. When Thomas Kehoe was working at this site, he also collected surface artifacts. In his collection, one previously unidentified point base has recently been classified to the Cody complex, stretching the occupation of this site back to the Paleoindian period. The 2016 artifact scatter consists of flakes, fire modified rock, expedient stone tools, projectile points, knapped scrappers, and faunal bone. Specifically relating to the Altithermal period, one Country Hills Projectile point base was found in the 2017 surface collection. This point type dates to ~8,345 to ~8,106 cal. yrs. BP (7,500 to 7,300 ^{14}C yrs. BP (Peck 2011)), which fits within the Altithermal period. The area around the site has been used as a cattle pasture since historic times, causing the artifacts within the pond basin to become heavily trampled by the cattle when the ground is wet. Despite the historic period use of this area, only one artifact was found dating to the historic period, which was a colorless glass vessel. The shape appears to be a whiskey bottle. A GIS analysis of the surface artifact pattering has demonstrated that the cattle trampling has caused the artifacts to be churned vertically in the pond sediments, but remain somewhat in place horizontally (Jansson and Thompson 2017).

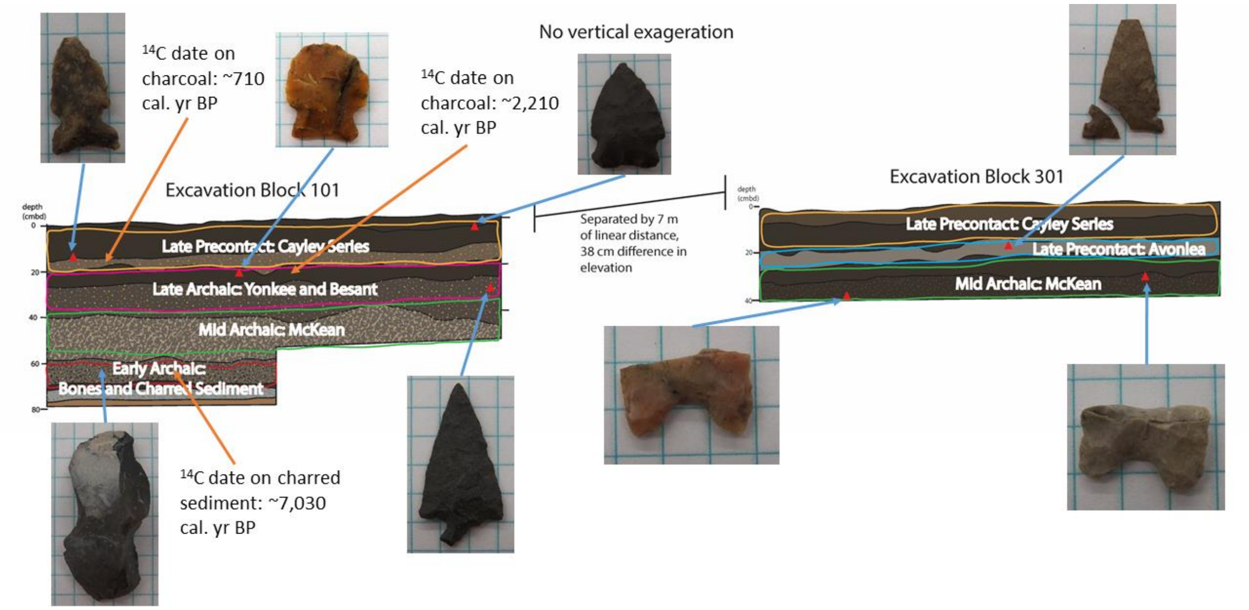


Figure 21. Cultural horizons uncovered in 2016 excavations.

CHAPTER 5: DISCUSSION AND CONCLUSION

There are three topics of concern in this discussion: 1) the concept of the pond as a water source; 2) paleolandscape reconstructions for the post-glacial period; and the Altithermal; 3) how the BBSs fits into previously proposed models of Altithermal impacts to human settlement.

The Pond as a Water Source

Water Supply Mechanisms for the Pond Water

The presence of water in the basin at this site is an important element in this analysis. Water certainly enters this basin via overland flow, but also arrives here through groundwater flow. Glacial tills with high permeability and annual recharge rates (like Stratum 1) are responsible for delivering large amounts of water to springs in this area (Cannon 1996a). These sediments are good aquifers because rainfall and snowmelt that occur in the uplands run downslope and are readily captured by the till (Cannon 1996a). Water remains in the till-aquifer until the aquifer contacts an impermeable layer (usually bedrock), and at this point, the ground water is forced up to the surface, and a spring is formed (Cannon 1996a). The bedrock intersects the modern ground surface in many locations around this site, which indicate locations where water is forced up to the ground surface. Since these till aquifers hold large amounts of water, they create reliable springs, which persist even during times of drought. Spring water has difficulty moving through the clay-rich layers within this basin, so the water likely enters the basin from the edges of the depression, where the clay is thinner or nonexistent.

Poor Drainage within the Basin

Strata 4 and 8 are clay rich layers, which restrict the movement of water through the basin fill sediments. The basin collects water throughout the year, but the water cannot infiltrate deep into the sediments because the clay-rich layers do not allow water to pass through. This creates a perched water table, where water collects above the impenetrable layer. This perched water table has caused some sediments in Strata 2, 4, and 5 to become gleyed in color, which is a common effect of a water saturation. Additionally, the basin center contains a significant buildup of calcium carbonate; containing about ten times as much calcium carbonate as the basin margin (Figures 17 and 18). This accumulation of calcium carbonate is probably a function of poor drainage. As the water evaporates, it leaves behind dissolved minerals. This large concentration of calcium carbonate was likely created by many seasons of standing water evaporating from the basin during dry periods. The presence of clay barriers, gleying, and calcium carbonate buildup show that this basin has poor drainage. Since there is little drainage, water is trapped within the basin and then evaporates during the summer months.

Recent Drainage of the Pond Basin

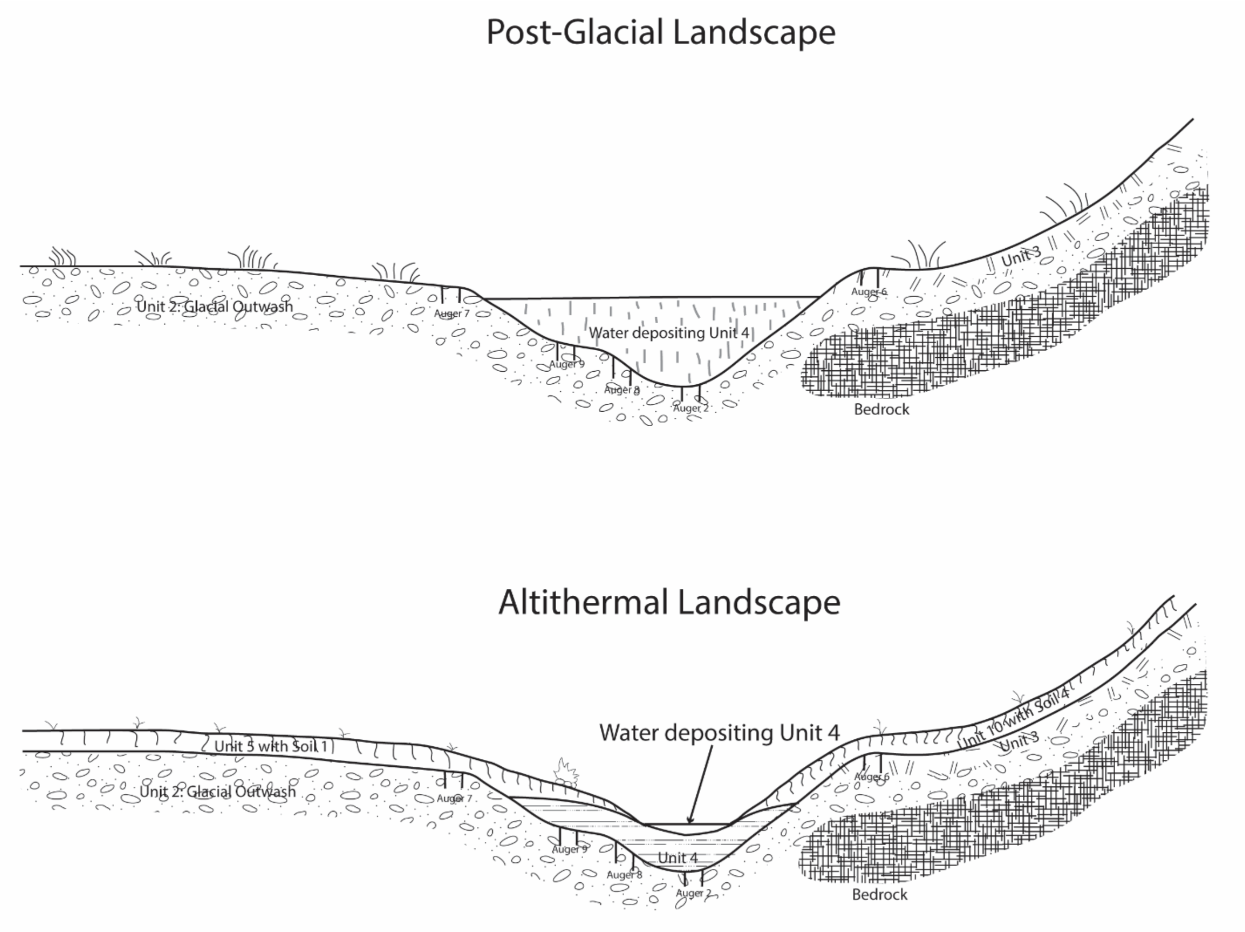
The water level in this basin has continued to be low in the historic period because the unnamed stream to west of the site began headcutting up its drainage, leaving steep banks along the stream channel. This deep channel has bisected the water table, and has caused the groundwater that once sat in the pond basin to empty out into the stream channel. The increase in erosive power of this drainage was likely fueled by the construction of a dirt two-track road that was cut through the northern section of the site in 1954 for petroleum exploration (Kehoe 2001:28). This road construction likely influenced local drainage patterns and exacerbated the erosional trend that was already occurring in this stream.

Paleolandscape Reconstruction

Late Pleistocene

During the late Pleistocene, this site was covered by large streams of glacial melt water that were depositing Stratum 2. Slightly after 13,290 cal. yrs. BP, the streams stopped flowing and the shape of the pond basin at this site was expressed in the outwash sediments. Being a low spot on the landscape caused by a glacial meltdown depression, water quickly filled the basin. This water was composed of both surface runoff and spring water from the underlying glacial till aquifer. The addition of the spring water made this basin a reliable water source, even when precipitation had been absent in the region for a long time. The reliability of this water source was likely one of its key attractions to both humans and animals in the past. The pond persisted in the basin throughout the rest of the late Pleistocene, and into the Early-Holocene, and allowed Stratum 3 to be deposited on the basin floor as fine sediment settling from suspension (Figure 22).

This area has a high potential for Paleoindian aged deposits because this landscape was not only deglaciated, but also recolonized by trees before ~13,250 cal. yrs. BP (Carrara 1989). The beginning of the Paleoindian period begins somewhere around 13,000 cal. yrs. BP, meaning that this area was inhabitable by the time the first Paleoindian people could have passed through this region. Though it was found out of context, the Cody Complex point in Kehoe’s surface collection shows that this site was occupied in the Late Paleoindian Period. Currently, no stratified cultural deposits at this site have been radiocarbon dated to the Paleoindian period, but Kehoe did report recovering a layer of nondiagnositic flakes and charred animals bones with cut marks in the glacial till. If this occupation is congruent with the age of the glacial till, and not reworked from a later deposit, this could represent an Early Paleoindian occupation. As mentioned before, the large piles of glacial till left on the landscape during this time were very unstable, and were prone to slumping and reworking. Any cultural occupation that occurred on this glacial outwash surface could have easily been buried by an episode of mass wasting shortly after their deposition. Taking this into account, artifacts within the glacial till at this site likely do date to the Paleoindian period, but many not be in their primary depositional contexts.


Post-Glacial Landscape

Altithermal Landscape

Figure 22. Landscape reconstructions for post-glacial and Altithermal periods at the Billy Big Spring site. Note the expansive pond in the Post-Glacial period, and the reduced but nonetheless present pond during the Altithermal period.

Early-Holocene

The cool early-Holocene at this site is marked by the continued presence of the pond water. The water was at its highest level during this period.

Mid-Holocene

The transition to the warm mid-Holocene occurred when the pond began to decrease in extent, which occurred sometime before ~8,415 cal. yrs. BP. At this point, the water retreated enough for the pond margin to become subaerially exposed. The pond never completely dried up during the mid-Holocene, since the basin center remained a clay depositing environment throughout this entire time (Figure 22). Once the margin on the western side of the pond basin became dry land, a habitable surface existed there for about 750 to 800 years until it was covered by a layer of tephra from the Mount Mazama eruption which occurred around 7,682 to 7,584 cal. yr. BP (Egan et al. 2015). After the eruption, eolian and overland flow processes continued to deposit sediment on top of the ash fall as Stratum 7. While this unit was being deposited, the first radiocarbon-dated occupation of this site occurred, represented by the "bones and charred sediment" in Stratum 7. One radiocarbon date on charred sediment dates the Bone and Charred Sediment occupation to ~7,030 cal. yrs. BP. While people were processing animal bones on the dry pond margin, the basin still held water that was depositing clay. In addition to this excavated occupation, the Country Hills projectile point from the surface finds also dates to the Altithermal period at ~8,345 to ~8,106 cal. yrs. BP (7,500 to 7,300 ^{14}C yrs. BP [Peck 2011]). This corresponds with the beginning of mid-Holocene drying, and shows that there were at least two separate occupations of this site during the Altithermal.

These dry mid-Holocene conditions continued for roughly 1,400 cal. yrs., until the pond water re-expanded across the basin shortly after this occupation (~7,030 cal. yrs. BP). The reduction in the water at the BBSs is very similar to what happened at Lofty Lake (in east-central Alberta). This lake was reduced to a shallow pond surrounded by wetland soil from ~9,460 to ~7,180 cal. yrs. BP (8,700 to 6,300 ^{14}C yrs. BP).

Late-Holocene

The late-Holocene includes the rest of the stratigraphy of this site, and is marked by the re-expansion of the pond water (Stratum 8), indicating a cooler, moister climate. The late-

Holocene sees a substantial amount of change, as sometime before ~2,210 cal. yrs. BP the pond water again eventually retreated to the basin center, and the basin margin resumed as a dry-land environment (Stratum 9). All of the later human occupations of this site occurred within Stratum 9 on the basin margin. During this time, the pond margin was a dry, soil forming environment that experienced occasion overbank flooding from the stream to the west of the site. The center of the pond remained wet enough throughout the year that Stratum 8 continued to be deposited up to the modern surface of the pond. Throughout the Mid Archaic to Late Prehistoric periods, the basin would seasonally dry up in the warm summer months, and people would camp on the floor of the basin, as evident by the large surface collection of artifacts within the basin. The Great Plains are windy, so a slight basin like this may have provided an appreciated wind break. This clay-rich layer was wet enough for the rest of the year that it apparently precluded soil formation. The artifacts accumulated on the surface of the basin in the center, and then were slightly buried by sediments carried in the water that returned to the basin. In the historic era, the area around this site has been used as a cattle pasture. Cattle walking across the site while the basin is saturated has caused these artifacts to be churned in the surface sediments.

In summary, this study concludes that a wet late Pleistocene/post-glacial environment began about ~13,920 cal. yrs. BP and persisted until ~8,415 cal. yrs. BP when drier conditions reduced the expanse of the pond water at this site with the onset of the mid-Holocene. Around ~7,030 cal. yrs. BP wet conditions returned and persisted for about 3,000 to 4,000 cal. years until sometime before ~2,210 cal. yrs. BP, when the water level retreated again. Since the Middle Archaic, the basin margin has been a dry, soil forming environment. These data coincide with much of the previous paleoenvironmetal work that has been done in this region.

Models of Altithermal Impacts and the Billy Big Spring Site

There is a both a stratigraphic record that the Altithermal occurred at the BBSs and an archaeological record that people used the BBSs during the Altithermal. Here, the data from this site are compared to the previously proposed ideas on Altithermal impacts. It is clear that this site does not support the Hiatus Model, since it was occupied twice during the Altithermal. The bones and charred sediment layer in Stratum 7, dated to ~7,030 cal. yrs. BP, along with the Country Hills Complex point dated around ~8,345 to ~8,106 cal. yrs. BP (7,500 to 7,300 ^{14}C yrs. BP; Peck 2011) both fit within the time span of the Altithermal at this site and within Barnosky's Altithermal timespan at Guardipee and Lost Lakes.

The fact that this site was used at least twice by people during the Altithermal supports Reeves' idea that the Altithermal did not have devastating consequences for people on the Northwestern Plains. Reeves (1973) posited that most of the known Altithermal-aged sites existed on the western periphery of the Plains (in the Foothills and Rocky Mountain Front) with none in on the Open Prairie. He suspected that there were Altithermal-aged sites on the Open Prairie but that archaeologists had not conducted surveys there, so they had not yet been found. The location of this site at the western edge of the Foothills (which is on the periphery of the Rocky Mountain Front) is congruent with the archaeology Reeves was discussing. Data from BBSs cannot address the question if Altithermal-age sites exist on the Open Prairies.

Considering the Foothills Hypothesis, since the BBSs is located in the Foothills ecological zone, it supports the part of this hypothesis that states that ancient groups used the Foothills zone during the Altithermal. The other part of the Foothills Hypothesis says that these ancient groups moved from the Open Prairies to the Foothills because the Open Prairies were experiencing too severe a drought during the Altithermal to support human life, is untestable without data on the distribution and ages of archaeological sites on the Open Prairies. For the Foothills Hypothesis to be verified, one would need to be able to prove that the Open Prairies were uninhabited at the same time that the BBSs was occupied. Without data addressing how arid the Open Prairies were during the Altithermal and without knowing if they were occupied by people, it is impossible to make a statement about whether people moved from the Open Prairies into the Foothills. It is possible that the Altithermal-aged occupations at the BBSs represent a continued use of the Foothills area during the Altithermal, and do not represent the movement of people at all, as Reeves expects. Barnosky's (1989) research on two lakes in the Open Prairies of Montana show that the Open Prairies did experience a decrease in available water during the Altithermal, since Guardipee Lake was dry from the onset of the Altithermal to approximately 100 years ago, and Lost Lake had increased salinity (indicating a lower water level) during the Altithermal but still held water. These data show that surface water did decrease on the Open Prairies during the Altithermal in some locations, but without analyzing the archaeology of this region during the Altithermal, it is impossible to know if this decrease in available water was large enough to affect people. It may have been the case that despite water levels did fall, they did not fall enough to impart real hardship on Open Prairies groups. Or conversely, this decrease in available water may have been enough to prompt Open Prairies groups to move to the Foothills zone, as the Foothills Hypothesis suggests. To fully address this question, more data needs to be gathered from Altithermal-aged archaeological sites on the Open Prairie to understand the ecological impacts this zone endured and its impacts on the resident human population.

BBSs also fits Sheehan's refugia model, since it was both used by people during the Altithermal and the pond at the BBSs also provided a water source. Sheehan predicts that Altithermal Refugia were located next to water sources generated by springs, because these would have been more reliable than precipitation-fed sources during a time of drought. The groundwater flow at this site is congruent with Sheehan's ideas about spring water reliability. Lastly, the archaeological record at this site also supports Oetelaar and Beaudoin's (2005; 2016) Mount Mazama Eruption hypothesis. These authors suggest that the Northwestern Plains were avoided for 500 to 600 years after the eruption, because the landscape was so devastated it could not support plant life. The bones and charred sediment occupation at the BBSs occurred 522 to 644 years after the eruption of Mount Mazama, which is congruent with this hypothesis.

In summary, the Billy Big Spring site fits all of the previously proposed models on the Altithermal, except for the Hiatus Model, which was already disproved in the 1970s (Albanese and Frison 1995). However, these models do not operate in conjunction. For example, the basis for Reeves' idea was that the Altithermal had no measurable effects on the populations of the Northwestern Plains. Contrast this with the Foothills Hypothesis, which stated that the Altithermal had a massive impact on the Open Prairies and caused people to leave this zone. The Altithermal Refugia model proposes that the Altithermal had a large, but variable effect across the entire Great Plains, whereas the Mazama Eruption Hypothesis says that the Altithermal had moderate impacts on the Northwestern Plains, until it was combined with the disastrous event of the Mazama eruption, which caused wholescale avoidance of the region for centuries.

Reeves' idea, the Foothills Hypothesis and the Altithermal Refugia Hypothesis cannot all be true for the entirety of the Northwestern Plains, since they each propose that the Altithermal had a different degree of effect. They are all verified in the Foothills at the BBSs because of the dramatic variability of the Altithermal in this region. Each of these models is correct within a specific context. Some locations on the Northwestern Plains were complexly unaffected by the Altithermal (the Lookingbill and Laddie Creek Sites for example), whereas other locations (like

Guardipee Lake) were heavily impacted. Due to this variation, one response cannot explain what happened across the entire Northwestern Plains region. So far, the Mazama Eruption Hypothesis has proved true for all sites that experienced ash fall from the eruption. Each of these models can describe a set of sites, but none of them can operate as overarching models for the region.

For example, Reeves' idea of "no effect" fits sites that observed no change during the Altithermal, like the Lookingbill and Laddie Creek sites. The Foothills Hypothesis fits the sites on the Open Prairies that were heavily impacted by the increased aridity. Even though no archaeology has been found at Guardipee Lake, this paleoecological site shows that some lakes on the Open Prairies did completely dry up during the Altithermal. It is reasonable to think that groups living nearby a lake that completely desiccated would move to find another water source. The Foothills would have been a good place to look for water, since the decreased temperature and increased precipitation of this ecological zone would have generated more surface water. The Altithermal Refugia Model fits the sites on the Northwestern Plains where their water sources may have been impacted by the climate of the Altithermal, but not severely enough preclude the human use of these areas. The BBSs is an example of one of these types of sites.

More strenuous testing of Reeve's idea of "no effect," the Foothills Hypothesis and the Altithermal Refugia Hypothesis require more data on the distribution of Altithermal-ages sites on the Open Prairies ecological zone. With this data, one could determine if Open Prairie sites were more often unaffected or strongly affected by the Altithermal climate, finding either more or less support for each of these hypotheses. A large-scale geomorphic investigation of Altithermal-ages surfaces is needed on the Open Prairies zone, but this fieldwork is complicated, since many of the Altithermal aged sites upstream have been eroded, whereas the downstream sites have been deeply buried (Mandel 1992, 1995). Prospecting the Open Prairie zone for Altithermal-aged archaeology could resolve the Foothills Hypothesis, Reeves' idea of no Altithermal impacts, and the Altithermal Refugia Model.

On a site-specific scale, the Altithermal did not have catastrophic impacts on human populations at the BBSs. It is clear that the mid-Holocene was a period of increased aridity, which caused the water source at this site to diminish in extent, but it nonetheless persisted as reliable source of water. Even though the Altithermal was a time of reduced water at BBSs, it may not have been an inhospitable place. In fact, both Reeves (1973) and Anderson et al. (1989) point out that the expanding grasslands during the Altithermal may have created more favorable conditions for bison, which would have been beneficial to the people living on the Northwestern Plains at the time.

In all, it is clear that the effects of the Altithermal were not as large on the Northwestern Plains as they were in some other regions, such as the Southern High Plains. In support of this idea, Meltzer (1999) observes that there is no evidence of well digging on the Northern Plains during the Altithermal and this suggests that above ground water sources were sufficient to supply the people of this region. It is apparent that climate change associated with the Altithermal occurred on the Northwestern Plains but that it probably was not large enough to cause much hardship on the occupants of this region.

Conclusion

This study interpreted the stratigraphy of the BBSs to understand its landscape evolution from the Last Glacial Maximum throughout the Holocene and to discover what kinds of impacts the Altithermal had on the people of this area. These data show evidence for two deposits of glacial till from the Pinedale glaciation, followed by a late Pleistocene to early-Holocene wetland environment that experienced drying with the onset of the Altithermal. Next, tephra from the eruption of Mount Mazama was deposited and dry conditions continued, during which the first radiocarbon-dated human occupation of the site occurred. In the late-Holocene, there was a temporary re-advance of the wetlands, but drier conditions soon returned and persist to the present.

Water was found to enter the pond basin at the site via spring discharge from an unconsolidated aquifer and via overland flow. During the Late-Pleistocene, a large pond existed in the basin, but during the Altithermal (mid-Holocene) the expanse of this water body retreated due to an increasingly arid climate. The oldest radiocarbon-dated occupation at this site occurred during the Altithermal, which has long been considered to be a period that was difficult for human life on the Northwestern Plains. Archaeologists have proposed five different hypotheses on how the Altithermal affected the ancient populations of the Northwestern Plains: the Hiatus Model, Reeves' idea of "no effect", the Mazama Eruption Hypothesis, the Foothills Hypothesis, and the Altithermal Refugia Hypothesis. Data from the BBSs supports all these hypotheses, except for the Hiatus Model. Due to the extreme variability of the Altithermal in this region, the author feels that Reeves' idea, the Foothills Hypothesis, and the Altithermal Refugia Hypothesis are correct for a specific suite of sites on the Northwestern Plains, but because the effects of the Altithermal were so varied, the human reactions to this phenomena cannot be explained simplistically for the region as a whole. More work needs to be carried out on the Open Prairie ecological zone to fully address the distribution of Altithermal-aged sites on the Northwestern Plains.

On a site-specific scale, data from the BBSs shows that the Altithermal did not have catastrophic ecological impacts at this site, and that human settlement persisted at this site throughout the period, except for a 500 to 600 year-long period after the eruption of Mount

Mazama. Other regions, such as the Southern High Plains, were unarguably strongly affected by the Altithermal, but these effects were not as strong in the Northwestern Plains. It is apparent that climate change associated with the Altithermal did occur on the Northwestern Plains but that it was not large enough to cause much hardship to the occupants of this region.

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