Remote Sensing Applications in Alberta Plains Archaeology

by

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Abstract

While research has been done in North America on the uses of various near surface geophysical techniques on european settler sites, the pre-contact sites of the First Nations people are often seen as too difficult to interpret separately from the environment they are in. This research set out to determine which remote sensing technologies are useful to pre-contact archaeological research being conducted on sites of Plains Cultures on the Mattheis Ranch managed by the Rangeland Research Institute of the University of Alberta. A Landscape Archaeological context was used to provide a structure with which human impacts on the landscape, and how the landscape they lived in might have impacted them, are put into perspective.

Aerial data is already widely used in Alberta archaeology and with large scale data sets available including satellite imagery, digitized air photos, and LiDAR providing historic, environmental, and landscape context to sites. Magnetic gradiometry is less understood, especially in a pre-contact context, but was shown to be useful in identifying potential cultural features for further investigation. Ground Penetrating Radar proved to be useful in conjunction with the magnetic gradiometry data at identifying cultural features that contained large enough physical objects within them, as shown at a suspected buried tipi ring at EfOx-80. At sites along Matzhiwin Creek, it also provided interesting information about site makeup and the environmental processes affecting them.

Overall, remote sensing was shown to be a useful collection of tools in directing archaeological research and hypothesis testing. Aerial data provides good context for near surface geophysical techniques which in turn offer information at a feature level

within sites. While Aerial data is often one of the first resources used when planning an archaeological project, near surface geophysics should be included in the planning stages of a project when ways of testing theories based on their results can be incorporated into the research design.

Dedication

In memory of Terry Gibson

(1954 - 2018)

Colleague, mentor, friend

“Stand back, I’m going to try science…”

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List of Abbreviations

AMS Dating: Accelerator Mass Spectrometry Dating

BP: Before Present

CRM: Cultural Resource Management

DEM: Digital Elevation Model

GIS: Geographic Information System

GPR: Ground Penetrating Radar

GPS: Global Positioning System

LiDAR: Light Detection and Ranging

NSG: Near Surface Geophysics

RADAR: Radio Detection and Ranging

RDP: Relative Dielectric Permittivity

RRI: Rangeland Research Institute

RS: Remote Sensing

UAV: Unmanned Aerial Vehicles

XRD: X-Ray Diffraction

Chapter 1 - Introduction

A variety of remote sensing (RS) techniques have been used to explore landscapes of the past all over the world. Some of those techniques, like the aerial methods of satellite multispectral data and LiDAR (Light Detection and Ranging), have been used for several archaeological applications on the northern plains. Others, such as near surface geophysics (NSG), have not been used as much because the ephemeral nature of the majority of the sites was not perceived as a viable source of data. As a result of this perception, much of the geophysical work that has been done on the northern plains has focused on settler structures such as forts, cabins and cemeteries (for example: Finnigan et al. 2012, Kubbinga et al. 2016, McKeand 2012, McKeand 2017), rather than on the pre-contact sites of the of the First Nations. As more information about how near surface geophysics can be used alongside the more conventional aerial landscape data was needed, this research was designed as a case study on the value of applying selected remote sensing applications on the known pre-contact sites on the Mattheis Research Ranch (*Figure 1.1*, next page).

This research was proposed and funded in 2017 as a way to further explore the known archaeological sites on the Mattheis Research Ranch while working within the Rangeland Research Institute's (RRI) mandate to preserve the prairie ecosystem. People have been having an impact on the land encompassed by the current ranch for centuries, and the use of remote sensing and near surface geophysical methods to assess the archaeology was seen as a valuable way to learn as much as possible about those impacts with minimal disturbance to the native prairie.

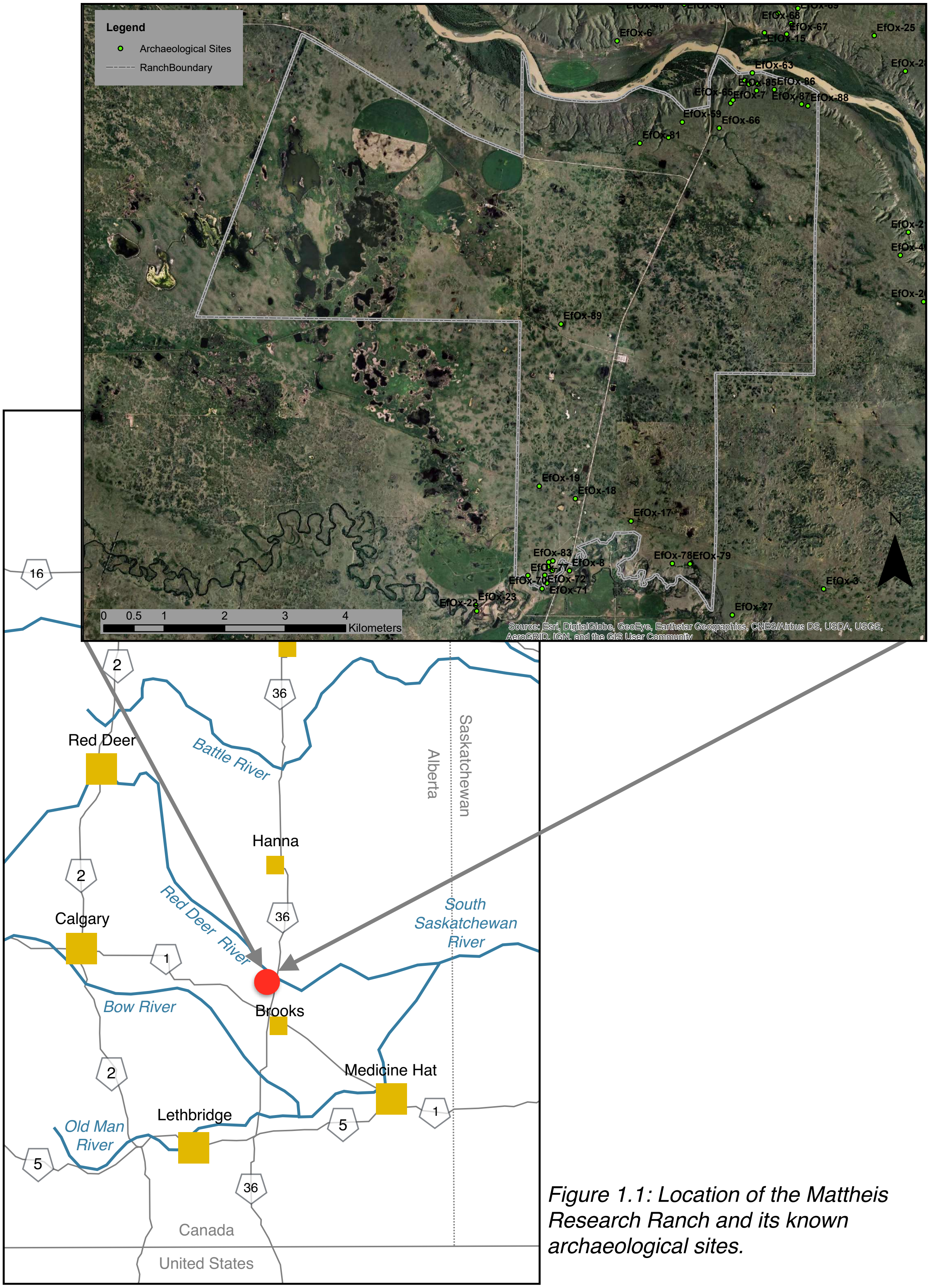


Figure 1.1: Location of the Mattheis Research Ranch and its known archaeological sites.

Three aerial remote sensing technologies were accessed as part of this research. They served to put human impacts on the land into perspective. Air photos taken in the 1950s offered a concrete way to evaluate changes to the landscape in the last 70 years. Satellite images provided a way to directly compare the air photos to the current environment and to put the sites into a larger environmental context. Plane-mounted LiDAR digital elevation models (DEMs) helped to form heritage potential models of the ranch after the 2012 field school (see Ives et al. 2020) and to inform hypotheses of how people might have been using the land (as in Fisher 2020).

The near surface geophysical technologies of magnetic gradiometry and ground penetrating radar (GPR) were seen as obvious geophysical technologies to experiment with because of their capabilities, and they have both been applied to pre-contact sites before (Gibson 1986, Gibson 2011, Conyers 2012, Munyikwa et al. 2014, Jollymore 2016). An increase in the use of—and reporting on—geophysics in Alberta began to emerge as a result of the post-2013 flood investigations undertaken by Alberta Culture and Tourism (Gibson 2017, Meyer et al. 2017, Roe 2017), but still requires research.

The goal was to see how these remote sensing technologies could work together to provide insight into research questions such as whether there are activity areas surrounding tipi rings and what features might be detectable at previously known archaeological sites. Finding features that can be detected leads to determining what information those features offer about how people might be using the site. As pointed out by Thompson et al. (2011), such questions lend themselves to a landscape archaeology approach that allows an archaeologist to consider past views of the landscape and imagine how that might be relevant to the people using it, as will be discussed in the next chapter.

With the above considerations in mind, this research aimed to answer the following questions:

1) What can the application of remote sensing techniques tell us about the history of archaeological sites in Alberta? What are some of the opportunities and challenges of these methods?
2) Can features such as the cairns and tipi ring rocks be mapped using aerial imagery to make a determination of how people are using sites?
3) Can near surface geophysics in the forms of GPR and magnetometry offer any insight into subsurface anthropogenic features at these transitory sites that were likely chosen with the location of the bison herds as one of the factors foremost in mind? People would have had to have been using these sites either very intensively over a short period, or repeatedly returning for these sites to become visible, persistent places.
4) What natural landforms are incorporated and/or exploited by the people using the area and what natural processes have the sites undergone since their creation? What are the conditions that might lead to those places being detectible through remote sensing?

This thesis will set the landscape archaeology within the cultural history of the ranch area to determine how people were using the land and what features might be left behind. That will be followed by an environmental history of the area which offers background into both the resources available for people to choose from and has an impact on the use and effectiveness of the remote sensing technologies employed. The next three chapters examine how aerial, GPR and magnetometry were each applied to sites on the ranch and evaluate their effectiveness. The conclusions reached will assist with planning future remote sensing work at plains archaeological sites that will make the most effective use of these survey tools.

Chapter 2 - Cultural History

Archaeology is fundamentally about the human experience, so understanding the cultural history of an area helps to provide context for research. It also provides a necessary framework for possible behaviours; the results of which can be seen in the artifacts and features left behind by those behaviours. This, in turn, gives archaeologists an idea of what kind of features to be looked for and where to look for them. It is the goal of the archaeologist to bear witness to the history of past peoples and bring stories that have been lost to time back to the fore. After all, "why else study the past if not to bring it back to life?" (Brink 2008: 7). To do this requires a method of considering human agency within the context of the environment available to them; in other words, understanding how people see the world around them.

Landscape Archaeology

> "… [Landscape archaeology] concerns not only the physical environment onto which people live out their lives but also the meaningful location in which lives are lived. … Landscape archaeology is an archaeology of how people visualized the world and how they engaged with one another across space, how they chose to manipulate their surroundings or how they were subliminally affected to do things by way of their locational circumstances." (David and Thomas 2008: 38)

Basing methodology in a landscape archaeological view allows the archaeologist to consider past views of the landscape and imagine how that might be relevant to the people using it. It considers how culture impacts an individual's decision-making process and how that will affect their view of the land available to them and how they will work with and move through it.

The challenge in using landscape archaeology is not falling into the trap of environmental determinism that ignores human agency (Trigger 2006, Praetzellis 2015). It is easy to proclaim things like "this is the best spot, so this is where the site is," but human factors and cultural ways of understanding the world will always play a part.

> Mae Williamson, a prominent middle-aged Blackfoot (president of the Blackfeet Arts and Crafts Association), reports that in her girlhood she asked the old people why the tipi rings are often located in what she would consider a poor camping spot, and they replied, "You young people are too particular about where you camp. We would camp wherever we had to, many times. We might have had to make camp when we were caught in a blizzard, and that is why you see those tipi rings in places that would not normally be used for camping, if we had a better place." (Kehoe 1960: 439)

To make sure that the human element is not overlooked, "[t]he ideal approach, … is one that relies on multiple, independent lines of evidence to reconstruct the patterned use of the ecophysical setting by human groups." (Oetelaar and Oetelaar 2006: 392)

In keeping with this ideology, the interpretations in this thesis rely heavily on past work into the study of *Nitsitiapi* (Blackfoot) life ways, as a model for understanding cultural decisions, as well as excavation and extensive artifact analysis work done by Dale Fisher (2020). In such digitally focused and technical work as remote sensing analysis, it can be easy to get lost in those digital details and forget that sites do not make themselves. Human decisions about what to do and where to go are what shape a site footprint.

Thompson et al (2011) argue that "for near-surface geophysics to become more common and widely accepted, the products of these methods must be clearly linked with broader theoretical concepts, or what we have termed 'inquiry- based archaeogeophysics'…" (Thompson et al 2011: p 196). That means there has to be careful consideration of the hypothesis put forward to ensure that it is framed in a human context.

> From an archaeological perspective one of the key properties of interest characterising a past place is the visibility of the environmental imprint left behind by the human agents who created the place, and whether that imprint produced a surviving archaeological footprint. (Beulieau 2018: 67)

By focusing on the human element we are emphasizing the human decisions that lead to sites becoming 'persistent places' (Thompson et al 2011: 197); that is, locations that people come back to or constantly use. The aim of this research is to see if near surface geophysics and aerial remote sensing can help to identify the kind of 'places' likely to be found on the ranch and how landscape archaeology can add to the understanding of how people used them.

Plains Archaeology and the Blackfoot People

There is archaeological evidence that people have been living on the Northwestern Plains that now include southern Alberta (*Figure 2.1*) for at least 13,300 years or more (Waters et al. 2015), following the retreat of the Laurentide ice sheet off to the northeast. People were originally drawn to the opening plains to hunt mammoths and other, smaller steppe animals such as horses and camels (Krause 1998, McNeil et al. 2004) before turning to hunting the bison herds that came to number in the millions over the Plains (Brink 2008). They became so good at it that by 5,800 years B.P. whole herds were being run over the cliff at Head-Smashed-In Buffalo Jump. Mass kills were occurring in "drives, or pounds, and opportunistic surrounds or ambushes at water holes

Figure 2.1: The Great Plains cultural region. (Courtesy of Cara Gadd)

or in breaks along watercourses," replacing the earlier pattern of repetitious single animal kills (Wedel 1961 in Krause 1998: 66).

Over this same time period, technologies changed along with hunting strategies. The most common artifacts to be preserved and to show stylistic and functional variability on the Plains are projectile points (Peck and Ives 2001). Some of the earliest stone points from the Early Prehistoric Period are understood to be from thrusting type spears that would have had a strong shaft requiring hunters to be up close to their prey and use their body weight to increase the force of their blows. The atlatl and dart and then the bow and arrow allowed hunters to get some distance from their prey and to increase the force of their blows at the same time (Bubel et al. 2012).

The sheer number of bison on the plains, and the success of the people hunting them, led to a wide variety of successful lifestyles by the time of European contact. In the north there were the Cree, who were able to set themselves up as traders with the arrival of the fur trade (Ray 1974, 1978). In the south, there were the people of the Plains Village tradition who were more sedentary and based their economy on horticulture and bison hunting (Drass 1998). In between, centred in the area that is now the southeastern Alberta, southwestern Saskatchewan and northern Montana were the likely ancestors of the Blackfoot people.

The archaeology of the site complex along Matzhiwin Creek points to an Avonlea (1,320 - 1,100 B.P. (Peck 2011, Bubel et al. 2012)) to Cayley Series (1,100 - 250 B.P. (Peck 2011, Bubel et al. 2012)) transition style of projectile points (Fisher 2020). Several calibrated radiocarbon dates from the sites on the south side of the creek— at EfOx-70 and EfOx-71—put the Matzhiwin Creek site(s) firmly in this time period, with results ranging from A.D 772-990 +/- 20 years (Ives et al. 2020), though EfOx-77 shows earlier and later dates from around 300 and 1700 AD (See *Table 3.1*, next page).

Looking at the cultural phases, the radiocarbon dates place EfOx-70 and EfOx-71 around the boundary between the Avonlea and the Old Women's Phase—which includes Cayley Series Prairie Side-notched points (Peck 2011, Bubel et al.

Activity Year	Lab Number	Specimen	Unit	AMS Date	δ 13C	Calibrated Date (2 σ)
2012	UCIAMS-122176	EfOx-77:50	AST-9	1145 ± 15	-17.8	A.D. 777-971*
	UCIAMS-122177	EfOx-77:51	CST-11	1785 ± 20	-18.3	A.D. 140-328
	UCIAMS-122180	EfOx-77:49	AST-9	1110 ± 15	-19.6	A.D. 893-981
	UCIAMS-122183	EfOx-77:48	AST-5	1110 ± 15	-19.2	A.D. 893-981
	UCIAMS-157341	EfOx-77:88	AST-11	1125 ± 15	-19.2	A.D. 889-971
	UCIAMS-157342	EfOx-77:136	CST-8	1085 ± 20	-19.4	A.D. 895-1014
	UCIAMS-157343	EfOx-77:164	CST-17	220 ± 20	-19.2	A.D. 1646-‡
	UCIAMS-157344†	EfOx-77:164	CST-17	205 ± 15	N/A	A.D. 1653-‡
	UCIAMS-157345	EfOx-77:220	CST-12	145 ± 15	-19.2	A.D. 1673-1943‡
	UCIAMS-197761	EfOx-77:1706	Area A Hearth	1100 ± 20	-18.9	A.D. 893-990
	UCIAMS-197762	EfOx-77:917	Level 11, NW Quad, C Trench	1755 ± 20	-19.2	A.D. 234-343
2017	UCIAMS-197758	EfOx-71:746	Ftr 1, North	1105 ± 20	-19.4	A.D. 893-987
	UCIAMS-197759	EfOx-71:737	Ftr 1, South	1100 ± 20	-19.3	A.D. 892-990
	UCIAMS-197760	EfOx-71:739	Ftr 2, South	1105 ± 20	-19.3	A.D. 893-987
	UCIAMS-131374	EfOx-70:1	Bone Bed	1180 ± 20	-19.9	A.D. 772-893
	UCIAMS-131375	EfOx-70:2	Bone Bed	1210 ± 20	-18.6	A.D. 726-885
	UCIAMS-131376	EfOx-70:3	Bone Bed	1120 ± 20	-18.8	A.D. 887-981
	UCIAMS-197755	EfOx-70:99	Bone Bed	1120 ± 20	-18.8	A.D. 887-981
	UCIAMS-197756	EfOx-70:88	Bone Bed	1085 ± 20	-19.0	A.D. 895-1014
	UCIAMS-197757	EfOx-70:85	Bone Bed	1120 ± 20	-19.1	A.D. 887-981
2019	UOC-11446	EfOx-70:535	Bone Bed	1159 ± 25	-19.4	A.D. 775-965
	UOC-11447	EfOx-70:536	Bone Bed	Insufficient Collagen	---	---
	UOC-11448	EfOx-70:532	Bone Bed	1134 ± 24	-18.2	A.D. 777-984
	UOC-11449	EfOx-70:538	Bone Bed	1142 ± 23	-19.2	A.D. 777-975
	UOC-11450	EfOx-70:539	Bone Bed	1062 ± 24	-18.8	A.D. 900-1022
	UOC-11451	EfOx70:537	Bone Bed	1148 ± 24	-18.8	A.D. 777-971
	UOC-11452	EfOx70:534	Bone Bed	1154 ± 25	-19.9	A.D. 776-969
	UOC-11453	EfOx-70:533	Bone Bed	1102 ± 23	-18.8	A.D. 791-991
	UOC-11454	EfOx-71:1133	Bone	1135 ± 25	-19.0	A.D. 777-984
	UOC-11455	EfOx-71:1134	Bone	1129 ± 24	-20.2	A.D. 778-988

*Calibrations in OxCal v4.2, IntCal13 (Reimer et al. 2013).
†Duplicate date, routine laboratory procedure for a split sample.
‡Calibrates out of range. Radiocarbon dating in this nearer time range is less reliable and precise, arising from atomic bomb and other effects.

Table 3.1: AMS Radiocarbon Dates for EfOx-70, EfOx-71 and EfOx-77 on Matzhiwin Creek. (Courtesy of John W. Ives in Fisher 2020).

2012). This makes the Matzhiwin Creek sites one of several sites around southern Alberta, southwestern Saskatchewan, and north-central Montana that exhibit transitional Avonlea/Old Women's components (Peck 2011), including the Empress tipi ring site (EfOo-130) and the Upper Kill site (DlDp-1) (Bubel et al. 2012). These transitional sites exhibit

> Avonlea material culture such as Avonlea points and/or Avonlea pottery (net-impressed, parallel-grooved, plain) in direct association with Old Women's material culture such as Cayley series points and Saskatchewan Basin complex: Late Variant pottery (Byrne 1973) or Ethridge Ware (Walde et al. 1995). The lithic raw material suite recovered at these sites tends to reflect local sources. There is strong continuity between subsistence strategies. Interestingly, evidence of fish occurs at EfOo-130. This is a rarity in later Old Women's sites but common in earlier Avonlea sites. (Peck 2011: 373)

The Avonlea and Old Women's phases are both considered to be part of the Late Precontact Period that was defined by the exclusive use of the bow and arrow technology and ceramic production (Bubel et al. 2012). Both phases are also recognized for large-scale bison hunting, though there is evidence of diverse substance strategies (Peck and Hudecek-Cuffe 2003). What is notable in the Old Women's phase are its Cayley Series projectile points and Saskatchewan Basin Complex: Late Variant pottery that occur together in many sites (Peck and Hudecek-Cuffe 2003, Peck and Vickers 2006)

The geographic distribution of the Old Women's Phase sites across south-central and southwestern Saskatchewan, southern Alberta, and northern Montana (Peck and Vickers 2006: 56) led archaeologists in Alberta to believe that the people of this phase are closely linked to the Blackfoot. Peck and Vickers (2006) explain that

> The first observations of southern Alberta by Europeans found the Blackfoot occupying much of the area. It seems reasonable to suppose the Blackfoot are responsible for much, if not all of the material culture named the Old Women's phase by archaeologists, although it is possible that Atsina/Gros Ventre and Tsuu T'ina/Sarcee may also be represented. (Peck and Vickers 2006: 56-57)

This line of reasoning points a direct path from the material culture of the Avonlea phase through to the Blackfoot people Europeans encountered during the fur trade and later. While it is almost certain that the path is more twisted and complicated than the one represented here—given the nature of a highly mobile people who would have been meeting, trading goods, and exchanging ideas with other groups they encountered—it is possible to follow a general thread.

Blackfoot Analogy

Following the logic above, and to help place these sites in a cultural landscape, a relationship to the Blackfoot people of today and recent history is assumed.

The Mattheis Ranch is centrally located within the traditional homeland of the Blackfoot-speaking people. The Blackfoot people say they have been on the land "since time immemorial" (Blackfoot Confederacy 2018) and, as shown above, it is not unreasonable to believe that their ancestors are represented by the Avonlea and Old Women's Phase of artifacts found in the area. Archaeological artifacts certainly point to a people who relied heavily on the buffalo hunt to supply meat for food and hides for tipi lodge covers, clothing, and robes, and are noticeably similar to those reported to be carried by the Blackfoot tribes encountered by the first European visitors to the area.

This analogy is made with the caveat that the Blackfoot as encountered at the time of European contact cannot be compared directly to their ancestors because cultures change, grow, and adapt over time. In the case of the Northern Plains people, the introduction of the horse had an incredible impact on how they moved through their world. As Bethke (2017) explains:

> The new demands of horse husbandry in turn required a reconceptualization of traditional land use as attention shifted from a focus on large-scale communal hunting efforts to a system devoted to the maintenance and growth of horse herds (Ewers 1955; Landals 2004). This work argues that these two realities combined to transform the Blackfoot worldview from a "hunter-gatherer landscape," where mobility and settlement patterns were determined by the needs of hunters, to a "pastoralist landscape," in which the needs of horses dictated how, when, and where the Blackfoot interacted with and moved across their homeland. (Bethke 2017: 798)

Since the 1880's when men like Grinnell (1892) and McLean (1890) were writing about their experiences on the Plains and recording Blackfoot stories, major changes to the Blackfoot world view have come about as the result of the reserve system, the pass system, and missionary teachings at residential and day schools. So, though a direct comparison is not possible, we do have a loose guide to how people lived their lives in the many stories left to the people still living on the land. We only have to ask. In the wise words of Andy Black Water (*Aahtsootoaa*), "Outsiders, waving their credentials, have dug up these offerings. They thought they could figure out the sites that way. *Instead, they should have just asked us*." (Blood & Chambers 2006: 8:04, *Emphasis added*).

Who are the Blackfoot People?

By the time Europeans made it to the area around the Mattheis Ranch, the Blackfoot-speaking people, who call themselves *Niitsitapi*, included it in their annual rounds. Grinnell (1892) recounts a story from Crazy Dog, an “old man” of the Blackfoot tribe that is their own history of how the *Niitsitapi* tribes came to be. In the story, an old man and his three sons, all grown and married, were starving. They were living far to the south on the other side of the mountains, when the old man had a vision that told him to cross the mountains to a “very big land” where they will find plenty of food. The sons and their father all agreed to follow the vision’s command and move their families to the other side of the mountains. When they arrived they could see plenty of game, “great bands of buffalo, elk and antelope,” (Grinnell 1892: 155), but the sons had no luck in the hunt. The old man made a “black medicine” that he rubbed on his eldest son’s feet that “enabled him to run so fast that he got right up beside a fat cow and killed her with one arrow” (Grinnell 1892: 155).

After they had feasted “[t]he old man gave his eldest son a new name. 'Hereafter,' he said, ' your name is Siks-i-ka'ho [Blackfoot]. It shall be the name of your children, too'”(Grinnell 1892: 155). When the younger sons protested, the old man told them to go to war and he would give them new names for themselves and their children. In the winter, the son who went east returned with scalps and his father named him “Kai'-nah [Bloods]” and the other son, who had gone south and also returned with scalps, he named “Pi-ku'n-i [Piegan] (Grinnell 1892: 156).

It is not entirely certain how the name for <u>all</u> the *Niitsitapi* came to be “Blackfoot” in English, but it is possible that name came from “their feet or moccasins always being discoloured by the black soil of the country where they lived or from the black surface of prairies recently burned over” (Grinnell 1892: 156). This also makes sense given that Blackfoot names are often given to tribes based on a perceived trait, and that name was then passed to Hudson's Bay Company representatives. Either way, the modern Blackfoot Confederacy is now made up of the Nations of Kainai-Blood Tribe, Siksika, Peigan-Piikani and Aamskapi Pikuni (Blackfoot Confederacy 2018).

How the Blackfoot lived

From a practical standpoint, seasonal rounds were based on the habits of the bison herds that were the main source of sustenance, but there were other important considerations as well. Vickers and Peck (2004) point out the importance of trees and and wood in the selection of winter campsites as a source of fuel for fires and as added protection from prairie storms. They would also have been an important source of lodge poles for their tipis and travois. Sources of vegetable foodstuff was also an important resource that would be visited during the seasonal rounds (Peck and Vickers 2006). Berry patches were visited annually to harvest chokecherries and saskatoons to mix with bison meat to make pemmican that could be stored in caches for lean winter months (Brink 2008: 230).

In addition to physical resources, Oetelaar and Oetelaar (2006) argue that Blackfoot movement around the northwestern Plains was motivated "as much by the need to fulfill social and ceremonial obligations as to collect resources." During their travels through the area, they followed in the footsteps of their ancestors and repeatedly visited a number of favourite camp sites …" (Otelaar and Oetelaar 2006: 383). They further explain that

> Throughout the year, nomadic groups reenact the wanderings of these mythological beings by following the same paths and stopping at specified places to perform activities and ceremonies in a prescribed order. During the course of

> these patterned movements, the prominent features on the landscape serve as mnemonic devices which elicit the appropriate narratives… In this fashion, the landscape becomes an archive or repository of traditional knowledge, and movement across the landscape becomes a journey through the history of the group. (Oetelaar and Oetelaar 2006: 376)

This makes the land itself an integral and active player in the everyday life of the Niitsitapi. This connection is probably best expressed by Leroy Little Bear:

> When aboriginal people and in this case… the Blackfoot people, you know, when we talk about land and our relationships to land … and some times we don't get to understand the deep meanings of it. And as a result I think many of us start to have what I refer to as an ID problem. … Really this ID problem I refer to is when the land doesn't recognize you any more. (Blood & Chambers 2006: 0:36)

He goes on to explain "We mark our territories by the stories, the songs, the ceremonies. Wherever you go, these sacred sites, certain things happen at those sites. That's how we mark out territory" (Blood & Chambers 2006: 9:18). Although there is the very practical reason to remember these stories and songs for the purpose of marking territory, the Niitsitapi also see the land as acting upon them or through them. "And so you could see that this notion about the songs, you know, they belong at certain places. And so they manifest themselves at those places. And so we as humans are in many ways just conduits for them wanting to come out" (Leroy Little Bear in Blood & Chambers 2006: 19:21).

With this deep connection to the land and the places on it, Oetelaar and Oetelaar (2006) suggest that "it is doubtful that any group would be willing to abandon the trail network when faced with shortages of critical resources, especially since such ecological disasters would be attributed to the failure of people in their dealings with the spirits" (Oetelaar and Oetelaar 2006: 386). There is no doubt that the decisions made by the Blackfoot people as they traveled had as large an impact on the landscape as it had on them.

The best winter forage for bison was a plant community dominated by *Festuca scabrella* or buffalo bunch grass which allowed for heavier grazing in the winter if accessed after it began its dormancy in early October. The grasses would lose a lot of their nutritional value while dormant, causing the bison to disperse into smaller groups over larger areas, but people could control where they went, somewhat, by maintaining the buffalo bunch grass through low intensity burns (Oetelaar 2014). The story of Old Man and the Fire leggings instructs on how fire should be used in the hunt (Wissler & Duvall 1908), and Fidler describes encountering large areas of burned or actively burning prairie during his travels, meaning the practice had carried on at least into the beginning of the nineteenth century (Oetelaar 2014: 22).

Limited agriculture was practiced in the growing of tobacco (Yellowhorn 2003), though other useful plants were likely also encouraged— probably as part of associated stories or ceremonies— to ensure they would be replenished the following year. For example, it is possible that people were encouraging tree growth along water sources near proven hunting grounds to ensure there would be wood resources and storm protection during winter months.

Indirectly, people may have been responsible for shaping landforms on the Plains through the bison they hunted (Barling 1995: 72).

> … because of the glaciofluvial origin of most sand dunes on the northern Great Plains, many dune fields occur in close proximity to major river systems. Consequently, the potential for past aboriginal disturbance induced dune activity

> is high in other areas such as the Brandon and Lauder Sand Hill, Manitoba, and the Middle Sand Hills, Alberta. (Wolfe et al. 2007:189)

This interaction is a crucial part of understanding the Landscape Archaeology of the area. Crucially, it shows that people were not just reacting to the land they inhabited, but actively working on it.

> Over long periods of time, the decisions and actions of the Blackfoot people, guided by their specific worldview, created the very ecosystem in which they lived. That is, the people created the fescue pastures in the foothills, managed the biologically diverse resource patches scattered across the landscape, and influenced the behaviors of animals, including bison. (Otelaar 2014: 26)

Understanding this world view and what its impacts are likely to be, allows the archaeologist to better understand the physical remnants of these behaviours and translate them.

Archaeological remains likely to be found on the ranch

Tipi rings

The most common archaeological features to be found on the Northwestern Plains are tipi rings. While there was some question early in the study of stone circles about what these might represent, in 1960 Kehoe declared that “the statements of all the informants bear out that tipi rings represent just what their name suggests: rings of stones employed by earlier Indian [sic] residents to hold down the sides of their skin tents” (Kehoe 1960: 435). While there are some circular formations that take the form of medicine wheels and other effigies, they are generally quite distinct from tipi rings due to added cairns, spokes and other rock formations that mark them as unique places. “Today researchers identify most of the stone circles as the remains of tipis but recognize that such functional attributions should be demonstrated rather than assumed." (Oetelaar 2003: 105)

Tipi rings are an archaeological phenomena created when the tipi is taken down to be moved to another location and, as part of that process, either the cover is pulled out from under the rocks, or the rocks are rolled off the cover. Generally, because the rocks are not packed up with the rest of the camp—they are only moved as far as is necessary to remove them from the lodge cover—they maintain a slightly looser footprint of where the tipi stood. Most confirmed tipi rings are complete circles of loosely placed rocks, while some have gaps, or a small line of rocks suggesting an entry way (Finnigan 1982).

Not all tipis required rocks to hold the lodge covers in place. Sheltered areas may have required very few rocks to hold the cover down, while other sites show evidence of the use of pegs made from modified bison bone (Finnigan 1982: 9). After European contact, canvas tepees were preferred as they were considered more portable and easier to erect (Mountain Horse 1979). Canvas rots quickly when allowed to sit on the ground, so using pegs would allow the owners to stretch it out above the ground where it would preserve better (Finnigan 1982). In some cases, pegs may have been used to hold down the cover of the tipi, but rocks would be used to hold the liner in place on the inside of the lodge as protection against winter winds (Kehoe 1960).

Kehoe's (1960) informants showed him several rings, identifying them as the remains of ancestor's lodges. They said the hide stretched more than the canvas so rocks placed on the hide would not roll off in the wind the they way they would off stretched canvas. Hide tipis usually required rocks to hold the edges of the hides in

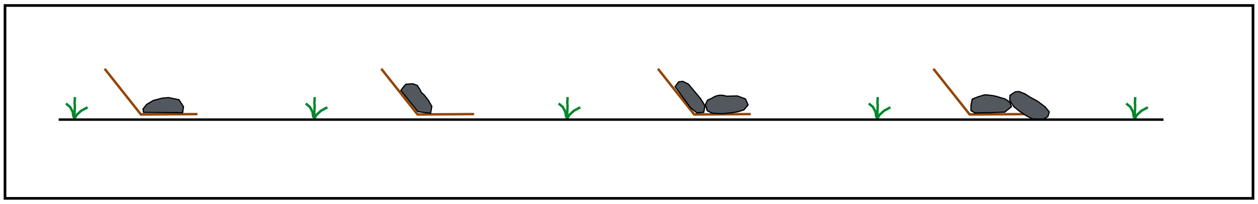


Figure 2.2: Possible methods of tipi stone placement. *(Adapted from Finnigan 1982).*

place in the prairie winds (see *Figure 2.2* for possible stone placements). Finnigan summarized the reasoning behind using rocks as anchoring devices saying, “[t]he four advantages of using rocks for an anchoring device are their availability, ease of placement, ease of removal, and the fact that they do no have to be transported from site to site.” (Finnigan 1982: 30)

Although in 1990 sites that included tipi ring features amounted to slightly more than 20% of the sites recorded at that time (Burley 1990: 343), research on them has been rather sporadic and not focused on excavation. This is because excavation of the rings is largely disappointing due to the meagre number of artifacts returned for the

Figure 2.3: Examples of Tipi exteriors and interiors. Left: Tipi and play tipi (Image courtesy of Whyte Museum of the Canadian Rockies, Archives and Library). Right: Inside tipi. Note the liner extending part way up the interior walls (Image courtesy of the Glenbow Archives).

amount of excavation work put in (Oetelaar 2003: 105). Ethnographic work undertaken by Kehoe (1960) at a Sundance in the 1950's suggests that this isn't particularly surprising as the inside of the lodges are kept clean of debris and almost nothing is left behind when the camp is packed up.

Interpretation of tipi rings is further complicated when spatial analysis is attempted because, while contemporaneity between nearby rings is often assumed, it is very difficult to quantify when there is nothing to date. Large clusters of ring features may be the result of one large group occupying the site at one time, or by the repeated use of a site by smaller groups over many years. This is something that may be better understood through the use of a landscape approach to the archaeology by examining whether camp features external to the tipis link the rings to one another.

The locations of tipi ring sites— whether all rings within them are contemporaneous or not—were more likely areas "selected for their spatial clustering of critical resources than by the location of bison herds" (Oetelaar 2003:123). When looking for these sites it is useful to consider that

> Concentrations of tipi rings along trails at specified distances away from the valley margins could also relate to the normal distances traveled in a day. However, it is important to remember that the Blackfoot conceived of distance as the number of days required to travel from place to place by normal mode of transport. Furthermore, the distance covered in one day varied according to terrain and the location of convenient camping places. (Oetelaar 2003:125)

Given that there are dozens of identified tipi rings on both sides of the Red Deer river valley around the Emerson Bridge on Highway 36, it is unlikely that they are all contemporaneous, but they likely offer a valuable clue as to what resources were in the area at their various times of occupation.

Effigies and sacred sites in the area

No effigies are known on the Mattheis Ranch as of 2019, but there are several to be found in the surrounding landscape. Vickers (2008) describes the effigies at Dorothy (EhPb-24) and Ward (EfPf-16) as Napi Figures and those at EiPf-1 (never observed by an archaeologist) and Napi's Grave as possible Napi Figures. They are thought by the modern Blackfoot people to show places where Napi lay down as he moved across the land. Vickers categorizes Napi figures as

> … formed by boulder outlines and are generally characterized by a rectangular body with simple extensions of the body forming the legs, out-turned feet, upraised arms, simple heads, heartlines (lifelines), and male genitalia. The figures are static frontal views. (Vickers 2008: 200)

The Medicine Man effigy is a Narrative Figure which marks the spot that a Blood, named Young Medicine Man (EePf-67) was killed by a Blackfoot in 1872 (Vickers 2008: 208). Wormington and Forbis (1965: 100) noted that "… effigy figures are widely spread over the Northern Plains, and are not restricted to Alberta or connected only with the Blackfeet." However, given the number of effigy figures found in what is now part of the land covered by the Blackfoot confederacy and the stories associated with them, many of the figures in this area likely are of Blackfoot ancestry.

Medicine Wheels

Another type of ceremonial site, the medicine wheel, is found throughout the Northern Plains. These features come in a wide variety of designs (see Reeves et al. eds. 2018) that are formed from large collections of rocks, in places that are believed to have been of ceremonial significance. Some of the ceremonial purposes are thought to be to commemorate important individuals, or the place of their death, or to commemorate the

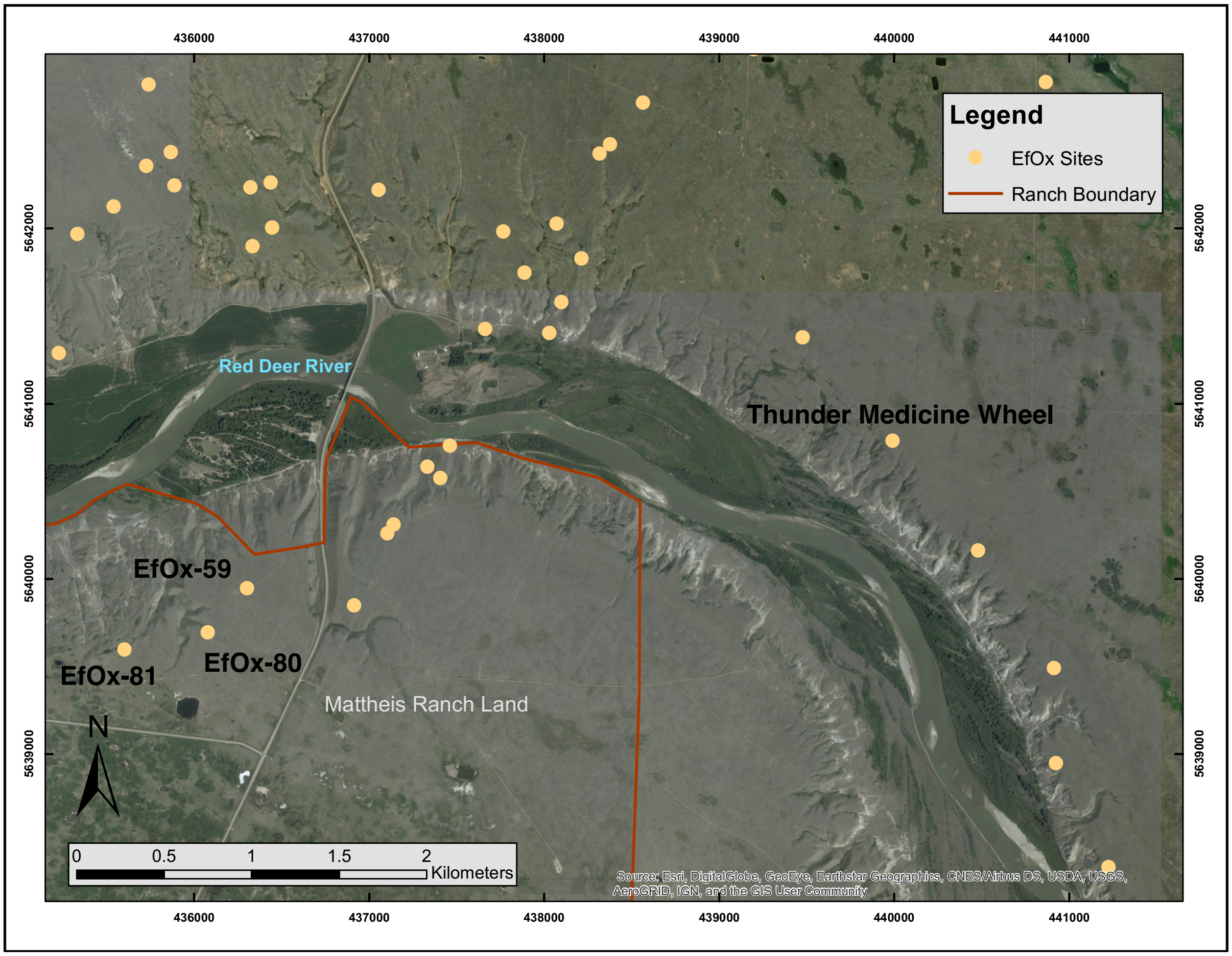


Figure 2.4: Location of the Thunder Medicine Wheel in relation to the sites examined in this thesis on the northeastern border of the Mattheis Ranch.

locations of important events (Calder 1977; Reeves et al. eds. 2018). As such, medicine wheels would have required regular visits and ceremonies to tell their stories and would have also been used as gathering places (Oetelaar and Oetelaar 2006). As a result, camp sites are often located near medicine wheel sites and further away as people traveled to them and away again.

There are no known medicine wheels on the Mattheis Ranch lands, but the Thunder Medicine Wheel (EfOx-28) is located almost directly east across the Red Deer River from the NE corner of the Mattheis Ranch (*Figure 2.4*). The site runs for nearly

500 m northwest to southeast along the upper valley edge of the Red Deer River with the medicine wheel in the northwest end of the site and 8 to 14 stone circles or arcs running toward the southeast on lobes along the prairie level of the river valley. This wheel is made up of a central cairn that appears to have been looted and a distinctive outer circle made of rocks smaller than those in the cairn (Hanna 2003).

The main challenge of these sacred sites is that they are very difficult to date without excavation — aside from the Narrative Figures that tell the story of an historical event. Excavation would irreparably disturb the sites, if that has not happened already in the form of looting, and it would damage relations with people still actively visiting the sites and leaving offerings.

Cairns

There are two cairns identified on the Mattheis Ranch so far (see *Figure 2.5* for the one closest to Matzhiwin Creek), but cairns are a challenge to plains archaeologists because they can be anything from burial locations, to piles of rock used as part of a bison drive, to rocks that farmers have moved out of a field for agricultural purposes or when putting fence lines into rocky ground . “The crucial defining criterion of a cairn is that it is a pile of rocks created by direct human action, regardless of the number of rocks it contains.” (Brink et. al. 2003: 209).

The crucial identifying difference between these various uses is context. Drive lines are usually piled in rows leading to cliffs or pounds, but they may or may not be preserved if farming has occurred on the land, or cattle have trampled the area. Burial cairns must be large enough piles to cover a body, but are often destroyed by looters.

Figure 2.5: Cairn at EfOx-77 in area C near Matzhiwin Creek. There is no real way to date the cairn except that it is old enough to have grown over and sprout lichen.

Quite often, the only indication of the age of a cairn is a buildup of prairie soil among the rocks, or the development of various lichen species on them.

Hearths

Hearths are often a focal point of heat, light, and food preparation, even in modern homes and recreational camp sites, so it makes sense that this would also have been true in the past. Mike Mountain Horse (1979: 25) fondly remembers of his boyhood home: “In the centre of the tepee was a hearth where a large fire kept the lodge cosy and warm, regardless of what the spirits were sending in the way of cold weather.” Kehoe (1960) describes one of his informants, Adam White Man, taking him to his father’s tipi ring:

> He also pointed out two cooking hearths. One was in the centre of the tipi ring, but nearer to the west than to the east side. It was not lined with rocks and was visible only by a slight discolouration of the soil. It would have gone unnoticed if not identified to me. The other fire hearth was located 21 feet east of the tipi ring, and consisted of two large rocks about 2 feet apart. Adam said that his father's family cooked inside the lodge only during bad weather, using the outside fireplace most of the year. (Kehoe 1960: 432)

Note that the hearth on the inside of the tipi did not have a ring of rock around it, but was only "visible by a slight discolouration." This is often the case of archaeological hearth features where their presence can only be inferred by observations of discarded artifacts, or through the use of sediment analysis or geophysical techniques (Sergent et al. 2006; Gibson 2015). Despite this difficulty, hearths, especially outdoor ones, are often an excellent source of information about daily activities, making them well worth examining either through excavation or as features that are part of the spatial analysis of a camp site. Although the hearth feature itself may only be visible in geophysical measurements, the artifacts left around them can be very telling.

Boiling Pits

Boiling pits are, as the name implies, holes in the ground that have been lined and used to boil water and long bones to extract the marrow and grease for use in pemmican or to cook soups and stews for meals (Oetelaar 2011). Pits were dug out and lined with a bison hide to hold water (Brink 2008). Stones, heated in a hearth, would then be transferred to the pit to heat the water, bones, or dinner.

Archaeologically, stone boiling pits are often difficult to identify unless they have been lined with rocks to help hold in the heat, or there is a distinct pit feature in an excavation. Their presence is often inferred by the presence of an associated hearth “showing traces of prolonged use, … quantities of fire-cracked rock and extremely comminuted bones…” (Oetelaar 2011: 70).

Remote sensing of Archaeological Features

So, why focus on features and not artifacts with remote sensing? Pre-contact artifacts in this context are too small and generally do not create a signal detectable by geophysical techniques, though collections of them that make up a feature may create one. Features, such as a well-used hearth area, will likely create a measurable signal on a magnetometer. While the individual artifacts associated with that hearth may not be measurable, there is a good chance that they can be found if the hearth is detected. People will often gather around the fire to tell stories and talk while they work on cooking, sewing, crafts, and tool making and leave the detritus of those activities behind. Looking at the feature scale rather than the artifact scale allows insight into the patterns of how people are using a particular space, so the focus of landscape archaeology is not on finding artifacts so much as looking for the area that is defined by where they are found.

The challenge is that sometimes the environment can obscure the difference between anthropological and natural features to the sensors in use on a project. The next chapter describes the environment available to the Blackfoot people and how it might impact the remote sensing results.

Chapter 3 - Environmental History

To better understand how the landscape of the ranch impacted how people chose to live on the land, a better understanding of its geographical history is necessary. This does not mean that the environment determines the culture that will develop within it, but rather that the physical environment provides resources and circumstances that must be worked with by the cultural domain. One environmental region does not mean only one culture can come out of it (Kroeber 1939, David and Thomas 2008, Beaulieau 2018); people bring a multitude of unique experiences wherever they go.

This chapter explores the environmental factors that the Northern Plains cultures were working with, so that some of their adaptations can be better understood. Some types of surficial geology can obscure cultural remains in the geophysical results; volcanic clays will not allow a GPR signal to pass through, and glacial till can contain naturally magnetic rocks that are difficult to distinguish from cultural artifacts. Trees and roots can obscure the ground from aerial sensors and hinder near NSG data collection. Understanding the environment provides crucial background into archaeological site formation and how those processes impact the results of the equipment used.

Location

This research is focused on a selection of the previously known archaeological sites on the Mattheis Research Ranch northwest of Duchess, Alberta. The ranch was donated to the University of Alberta in 2010 by Edwin and Ruth Mattheis with a mandate to maintain the land as a location for research of all types on relatively undisturbed prairie. Approximately 4,000 hectares of a total of about 5,000 ha. is native grassland while the remainder includes irrigation fed wetlands and crops (Rangeland Research Institute 2018). It is managed as a custom grazing operation and "since being acquired by the University of Alberta in 2011, the ranch has been rotationally stocked with approximately 800 beef cattle for an average of 6 months each year, beginning in early May" (Rangeland Research Institute 2018).

The extensive area of largely undisturbed grassland makes the ranch an ideal location for finding intact or minimally disturbed archaeological sites. There are 10 known sites along the south edge of the Red Deer River valley at the north end of the ranch, and another 14 sites located along the Matziwin Creek on its southern edge. While "grazing can have a marked and long-lasting influence on plant community composition" (Natural Regions Committee 2006: 89), the soils below the surface remain relatively undisturbed compared to tilled farm land.

Northwestern Plains environment

Today, the Canadian northwestern plains are an area of generally low relief with elevation decreasing across the prairie provinces from the high points of Rocky Mountains in the west down to Hudson Bay in the east. In southern Alberta the plains are incised by the Red Deer, the Bow and the Oldman rivers that converge to become the South Saskatchewan River. The rivers begin in the eastern slopes of the Rocky Mountains and flow east to join with the North Saskatchewan and eventually into Lake Winnipeg. The dramatic landscapes created by the river valleys offer areas of increased animal and vegetable diversity compared to the rolling plains above (Muhs & Wolfe 1999: 185).

Climate

The landlocked, continental setting of the northwestern plains leads to long cold winters and warm, but short summers. Three main air masses influence the region: cold, dry arctic air from the northwest frequently brings in freezing temperatures from the north and northwest; warm dry Pacific-derived air that is the prevailing source of prairie winds; and, not as frequently, warm moist air derived from the gulf of Mexico that can bring winter storms and summer downpours (Muhs & Wolfe 1999). Seasonality is an important fact of life on the plains. Berries, seeds, tubers, and even water are only available at very particular times of the year.

Rainfall on the prairies generally increases from the eastern slopes of the Rocky Mountains going east out towards Manitoba. Southern Alberta is in a rain shadow/ chinook wind region caused by prevailing winds from the west coast. The air is forced up and over the Coastal and then Rocky Mountains, and drops a lot of its moisture on the western slopes in the form of rain or snow as it rises. The air coming back down the eastern slopes warms as it descends and has a lower humidity, creating Chinooks or "snow-eater" winds (Beaudoin 2003: 14).

The winds are part of what make southeastern Alberta and southwestern Saskatchewan the most arid region of the Canadian prairies, with the exception of the Cypress Hills.

> The wind is one's almost constant companion on the open plains. Despite the discomfort it brings, it is an important factor in the winter survival of large ungulates, particularly bison and pronghorn, by clearing areas of snow and exposing grasses for forage…" (Frison 1998: 140-141)

The vegetation on the northwestern plains reflects the low moisture levels with the pre-settlement vegetation consisting mainly of short or tall grass prairie (Frison 1998; Muhs & Wolfe 1999) that are adapted to summer drought (Natural Regions Committee 2006).

Landscape

The landscape of the Mattheis Ranch began to be formed after the genesis of the Rocky Mountains roughly 55 million years ago. In alternating periods during the Cretaceous (146 to 65 million years ago) and early Tertiary (65 to 57 million years ago) periods (Press & Siever 1997), material eroded from the newly formed mountains and clay and silt deposition from rises in the level of the Bear Paw sea accumulated (Dawson et al. 1994).

For the rest of the Tertiary Period and the Pleistocene Epoch of the Quaternary[1] Period, the plains were eroded by rivers flowing west-to-east and southwest-to-northeast from the newly formed Rocky Mountain Front Ranges that deposited their sediment load off to the east (Dawson et al. 1994). These rivers formed valleys, many of which were filled with locally thick deposits of poorly sorted glacial till under glaciation (Barling 1995).

East of the foothills of the Rocky Mountains, the northwestern plains are mostly dominated by features of lower elevations. Some are remnants of the last glacial maximum like the Beaver Hills east of Edmonton that are a "hummocky "knob and kettle" terrain of the [Cooking Lake moraine that] forms a patchwork of depressional areas, many of which support wetlands and small lakes" (Beaver Hills Initiative 2004: 1).

[1] The Quaternary is a geologic period of time that began 1.6 million years ago and continues to the present that includes the Pleistocene and Holocene Epoch. The holocene began roughly roughly 10-15,000 years ago in Alberta with the retreat of the glaciers. In this context 'Quaternary' is used to refer mostly to the Pleistocene Epoch.

Other areas, like the Cypress Hills, were areas where the landscape had a hard cap that was never completely covered by ice and therefore did not erode during the glacial period. Afterwards, rivers were forced around the peaks, further lowering the surrounding landscape (Klassen 2017).

As the glaciers began their retreat to the northeast, proglacial lakes covered most areas at one time or another, depositing glacial lacustrine sediments of mostly clay and silt (Muhs & Wolfe 1999, Barling 1995). Topographic relief on the prairies comes in the form of the dramatic vistas created by rivers that have deeply incised their valleys since the last glacial retreat leaving networks of coulees and wide river valleys that open like a fissure in the otherwise flat or rolling landscape (*Figure 3.1*).

Figure 3.1: View northwest down the coulee from EfOx-80 to the Red Deer River valley shows the coulee leading down to the wide river valley at the bottom.

These slight—when compared to the Rocky Mountains—topographical changes created several areas where increased resources were available as plants and animals took advantage of geographic differences (Frison 1998). Minor differences in slope, aspect, and access to ground water can all produce significant changes to plant communities (Natural Regions Committee 2006), making areas where those plant resources border the open plains incredibly resource rich for animals and their human hunters. Dramatic examples of this can be seen in the Bow, Old Man and St. Mary's Rivers in southern Alberta, and the Red Deer River valley area under study here does not disappoint.

Red Deer River

The Red Deer River valley was one of many valleys that began to take shape during the period of ice retreat and glacial lake drainage (Barling 1995). In the early part of the post glacial period, the Red Deer River experienced a period of rapid downcutting attributed to a combination of high discharge coming from the proglacial lakes running through a highly erodible underlying bedrock. Glaciostatic uplift—the rise of the earth's crust as the weight of the glaciers and their meltwater was removed—would have enhanced the already rapid downcutting. In some areas, this downcutting created new channels, but there are parts of the valley where it seems to have followed preglacial valleys and postglacial spillways.

As discharge from the proglacial lakes declined towards the mid-Holocene, the incision rate of the Red Deer slowed, allowing for the deposition of the fine grained alluvium of the lower valley upstream from the Mattheis Ranch (Barling 1995, Shetsen

1987). These newer, finer silt deposits on the valley floor work far better for the GPR and magnetometry equipment than the glacial till as they are far more distinct from any potential archaeological remains than the coarse gravel sediment (Shetsen 1987) along the river on the north edge of the ranch.

Matzhiwin Creek

Matzhiwin Creek was formed during the Holocene through episodic erosion that was rapid and short lived, but that had lasting effects on the landscape and on where the creek bed now lies. Dates from alluvial fan deposits in the downstream reach of the Creek suggest that the majority of this incision was completed by about 6,000 BP, basically setting the valley seen today (Barling 1995). Between these episodes of erosion, the creek channel was generally stable or was aggregating aeolian sediments, with periods of soil formation. Aeolian deposits from the Duchess Sand Dunes located north of Matzhiwin Creek, between it and the Red Deer River, give evidence of periods of dune instability.

Barling (1995: 75) suggests that that "[i]f climate has been a dominant influence on channel behavior in Matzhiwin Creek it appears that episodes of channel aggradation occurred during warm/ arid conditions and episodes of incision occurred during cool/ moist conditions." He does caution that climate cannot be considered the only factor influencing stream flow, especially earlier in the Holocene.

There are areas along the creek where Empress formation sands and gravels outcrop. They are conglomerates that inhibit stream incision and affect the rate of lateral stream migration. An outcrop just upstream (west) of EfOx-70 may be one of these that forced the creek north into an old creek scar that is now at the base of the terrace that EfOx-77 sits on.

Duchess Dune Formation

The majority of the Mattheis Ranch is situated right on top of the eastern portion of the Duchess dune field (Wolfe et al. 2002) as shown in *Figure 3.2*. These dunes are the source of aeolian deposits found in Matzhiwin Creek, the Red Deer River, and as far east as Dinosaur Provincial park (some 35 km away as the wind blows). The east-southeast orientation of the dunes indicate a prevailing wind direction coming from the northwest, as are most of the dunes north and east of Calgary (Wolfe et al. 2002).

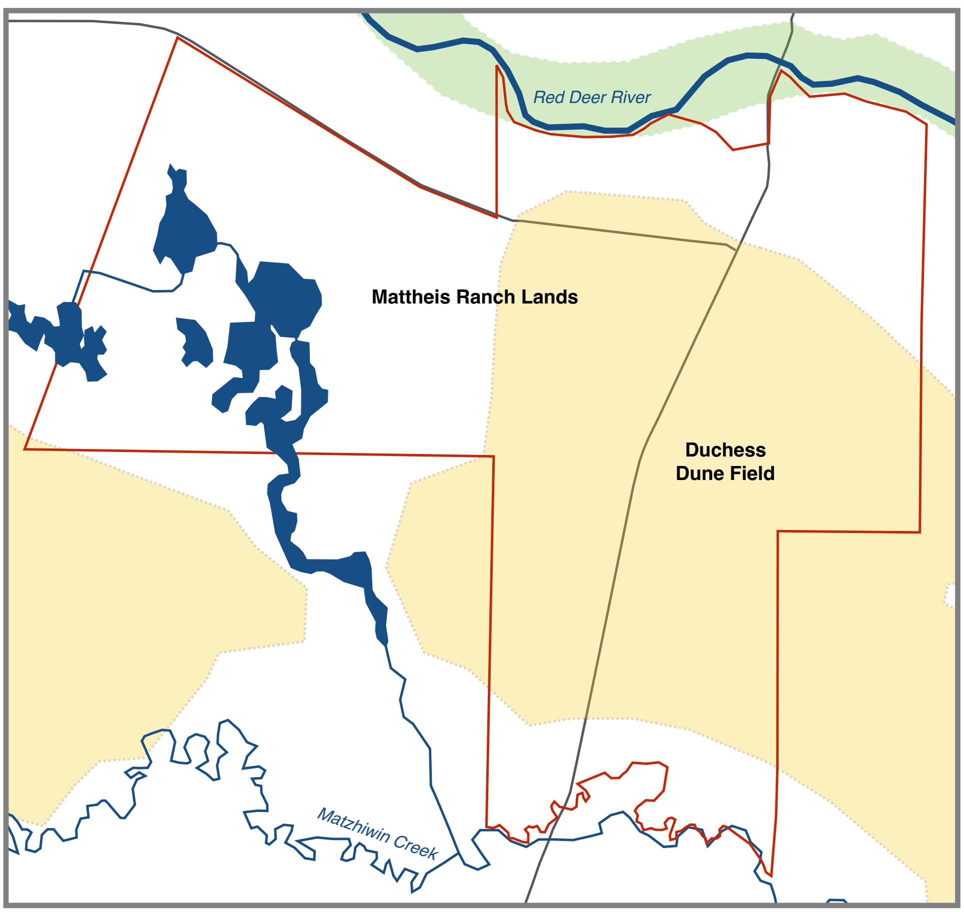


Figure 3.2: Location of the Duchess Dune formation (adapted from Wolfe et al. 2002).

Paleoclimatic proxy record studies show that along with affecting creek development, regional moisture levels also impacted aeolian activity and palaeosol development in the dunes (Wolfe et al. 2002).

The dune field is actually divided into two distinct sections by a linear region west of the southern sections of the Mattheis Ranch, that are currently wetland areas of open water. This interdune corridor predominantly consists of ice-contact glaciolacustrine and glaciofluvial deposits up to 25 m thick (Shetsen 1987, Wolfe et al. 2002) The wetlands are the result of work by Ducks Unlimited Canada in 1952 (Rangeland Research Institute 2018), but air photos collected in 1950 to 1952 (Alberta Energy and Natural Resources 1952) show signs of flooding in the form of salt flats, suggesting that water has long collected there, making it more available for vegetation. This area likely always contained plant resources that could not survive on the drier sand dunes surrounding it.

Like the Bodo sand hills (Munyikwa 2014), these dunes are poor for agriculture and therefore never tilled, so they were used for cattle instead. Evidence of use by bison are all over the ranch in the form of a rubbing stone in the northeast corner of the ranch, wallows along the northern upper valley margin of Matzhiwin Creek on the south end of the ranch, and of course the bone refuse to be found in the archaeological sites along both Matzhiwin Creek and the Red Deer River. Bison herds also likely had a significant role to play in affecting the landscape and changing vegetation and soil conditions (Wolfe et al. 2002, Barling 1995).

There are two environmental features listed by the provincial Natural Regions Committee (2006) present on the ranch lands that likely made this area an appealing place to camp for past populations:

1. In the dry mixed grass natural subregion trees are absent except along rivers or in deep coulees where subsurface water is available. This makes the riparian areas more diverse ecosystems with open plains at the top of the valleys offering one ecosystem of resources and the river valley offering another.
2. Hot summers, high solar inputs, high evaporation, and long cold winters with low snow cover mean that forage for bison is not too deeply buried in snow. The river valleys nearby offer shelter from the worst of the prairie winds and wood for fuel, and there is easy access to the plains above.

Oetelaar and Oetelaar (2006) suggest that this area would be part of summer seasonal rounds with people retreating to the area of the Rocky Mountain foothills in winter where there would be more moisture. It is possible that this area may have been used by one of the neighbouring groups in winter, or that the site was used in spring or fall. If occupations are more recent, the sight lines from the prairie and the natural topography of the river valley where the Emerson Bridge campground currently sits make a perfect natural corral for horses (discussed further in the next chapter).

Place names

First Nations place names often give clues to the history or use of a place (Thornton 2008). Sometimes the name documents a cultural or historical event; for example, Sounding Lake refers to a story in which Thunderbird is fighting serpents for the earth and sky and gets pulled into the lake (Cutknife 2018). Other names are given based on their resemblance to something else for the purposes of navigation such as Crow's Nest pass or Chief Mountain (Cutknife 2018). Still others are named for the resources available such as Manyberries south of Medicine Hat (Aubrey ed. 2006: 203) or the Beaver Hills east of Edmonton (Aubrey ed. 2006: 23). With this in mind, the place names of the ranch were examined for clues as to their past use.

Red Deer River

The name of the Red Deer River is popularly attributed to early Scottish settlers or Hudson Bay Company employees who "mistook" the elk in the area for the "red deer" of their homeland. While the similarities are striking, it is more likely that they understood the difference between them, and named the elk after the red deer, leading to the name of the river, and eventually, the city of Red Deer.

The name appears on maps of the river dating at least as far back as 1797 (Aubrey ed. 2006: 271). The Cree name for the river is *was-ka-sioo*, which means "Elk River" (Donovan and Monto 2006: 188-189), suggests that the elk had long been frequenting the area where the City of Red Deer is today.

Speculation on the name Matzhiwin Creek

The origin of the name of Matzhiwin Creek is slightly more nebulous than the Red Deer River. In the volume "Place Names of Alberta" (Karamitsanis ed. 1992:78) the origin is simply listed as "The precise origin for the name of this feature is unknown."

Beaulieu (2018) found evidence on Grazing maps from 1881 that the Creek might have been called "Beaver River" or "Beaver Head River", which would make sense given that there are beaver in the creek to this day (*Figure 3.3*).

A suggestion from one of the field school students in 2019, led to investigating the Cree term mâcîwin meaning "hunting" or "the hunt" (Wolvengrey 2013). The current spelling and pronunciation of 'Matzhiwin' suggest that the word is of Plains Cree origin

Figure 3.3: Looking south at one of two beaver dams across this area of Matzhiwin Creek on the northwestern edge of EfOx-71.

in which the “c” usually represents a “ts” sound (Wolvengrey 2013). The fact that it is a Cree word rather than Blackfoot may be due to Cree traders using the creek to hunt in the fur trade era and possibly earlier, or it may be a Cree translation originating from Blackfoot creating a calque.

Conclusion

> “Seasonal changes dominate life on the Plains. Animal behavior changes seasonally and had to be understood by Native Americans to ensure success in hunting. Wild food plants—whether seeds, berries, fruits, leaves, roots, tubers, or blossoms—appear and disappear rapidly, and careful scheduling of group

> movement in response to their periods of availability was necessary. Late spring through early fall is a time of food abundance, easy travel, and relative comfort. Late fall through early spring is a time of rapid and unpredictable changes in weather and the availability of food. Winter blizzards followed by prolonged periods of subzero weather inhibited normal food procurement, and survival required some food storage." (Frison 1998: p 140-141)

The majority of the known archaeological sites on the ranch were located during Cultural Resource Management (CRM) surveys mandated when electrical transmission lines were developed along the eastern side of the ranch or when oil and gas infrastructure were put in (Girard et al. 2012a, Girard et al. 2012b, de Guzman et al 2013a, de Guzman et al 2013b Stewart 2014). The remainder were located as part of field school activities under the University of Alberta's Institute of Prairie Archaeology field school (Ives et al. 2020). Their proximity to stone circle sites on the north side of the Red Deer River on both sides of Highway 36, and the Thunder Medicine Wheel suggest this is an important area within seasonal rounds to many groups, over a long period of time (Beaulieau 2018).

This is the environment people had available to them. To gain a better understanding of how people might have seen that landscape, aerial data was employed.

Chapter 4 - Aerial Data

To better understand how people might have been making use of their environment and how modern land use might have changed it, the landscape was examined through the use of historic air photos, satellite imagery, LiDAR data and drone imagery collection.

Past use of Aerial data

Aerial Remote Sensing collects various forms data about the ground from a height above it, without coming into physical contact with the surface. Its first use in an archaeological setting is credited to Lieutenant Phillip Henry Sharpe of the Royal Engineers' Balloon Section who took three photographs of Stonehenge from a tethered balloon in 1906 (Parcak 2019: 32). The use of air photographs in foreign and domestic intelligence led to the development of spy satellites that could collect information without entering enemy air space and therefore without risking a pilot. Once these technologies were made available to the public for use in applications such as monitoring oceans, weather patterns, and land management and monitoring, archaeologists were able to learn more about them.

The success of the use of radar imagery collected by the Space Shuttle Columbia in the Eastern Sahara to direct archaeological expeditions (McCauley et al. 1982), made headlines in 1982 (Wilford 1982) and basically began the field of what NASA called "space archaeology." Since then, instruments attached to drones, planes, and satellites have given all people the ability to visualize the world from the continental scale of kilometres or more, down to the very human scale of a few centimetres at a time. The expanded ability to put sites in the context of their "physical and human geographies" (Harrower and Comer 2003: 2) has become a vital portion of understanding human decision-making processes of the past.

Aerial data is often the first response to questions of landscape archaeology because it provides a landscape-level view that can often tie sites together, such as those along Matzhiwin Creek. On the Mattheis Ranch several types of aerial data are available including historic air photos, satellite imagery, and LiDAR digital elevation models collected by plane. In 2019, imagery data was also collected by Unmanned Aerial Vehicle (UAV or drone) of each of the sites inspected by the field schools in 2017 and 2019.

Types of Aerial data available for the ranch

Historic Air Photos (1950-52)

Air photos are, as the name implies, photos taken from the air, usually from a plane, though balloons, scaffolds, building tops and drones have also been used. Air photo survey from planes flying at a set altitude are generally taken in a grid of overlapping photos that covers an area of interest in a planar or oblique view. Overlapping planar photos allow black and white images to be viewed stereoscopically through purpose-made lenses.

Air photos have been collected by the provincial government of Alberta since 1949 (Government of Alberta Provincial Geospatial Centre Air Photo Library), and private and municipal air photo surveys extend back to the 1920's. This collection of photographs, taken over just about 100 years in some areas of the province, offers a glimpse of the change in the provincial landscape over that time. Archaeologists and historians can observe as buildings are erected and torn down, land is developed, highways built and cities grow. During World War I in Europe, intelligence photographs were collected of the front lines that are still used by archaeologists looking for hints of unrecorded site locations or as a way to see how known site locations have changed (Parcak 2019: 32).

In the last few decades, air photos have evolved from film cameras taken from planes, to digital cameras operating from drones, which will be discussed shortly. This makes the data even cheaper to collect and drones can be flown at very low altitudes allowing for sub-centimetre resolution. The air photo data used here was part of a project collecting photos from 1950 to 1952 and flown at an altitude of 23,000 feet (7010 meters). It was obtained from the Air Photo Library of the Provincial Geospatial Centre of the government of Alberta in a digital format that was then georeferenced for use in ArcGIS with other cultural and environmental spatial data collected for the study area. The resulting digital resolution is roughly 1 meter per pixel, though the accuracy of its georeferenced location is more like +/- 5 m due to the difficulty in finding landmarks on the Alberta plains that haven't changed over the last 65 or more years.

Satellite Imagery

Satellite Imagery came about as a direct result of air photos. Much like air photos, their original use as a way to spy on the activities of other countries opened the door to many more applications in land management and monitoring (Parcak 2019: 32).

Satellites are generally equipped with sensors that detect electromagnetic energy within and outside the visible spectrum of light into the infrared and beyond. Multispectral sensors group wavelengths into "bands" so each colour of light can be analyzed individually. This allows for detailed vegetation analysis that examines how much of each band of light each species of plant reflects, allowing foresters to estimate how much of a desirable tree species a target harvest area has. Active sensors that collect data on the return of an emitted signal on the longer RADAR (Radio Detection and Ranging) wavelength (8-12 GHz), are only reflected by dense materials such as rock, making it the ideal technology to see the bedrock formations below the loose sand in the Sahara desert (McCauley et al. 1982).

In Alberta and the northwestern plains, satellite imagery has been used in applications from forestry management to monitoring the effects of fire, and grassland health and productivity (Finnigan 2013). Archaeologically, multi-spectral data has been used in predictive modelling in the search for unknown archaeological sites. Long running satellite programs like LandSat — operated jointly by NASA and the USGS — mean that there is now a nearly fifty year back catalogue of earth observation data for the entire planet from eight satellites so far (USGS 2018). That means there is 30 meter resolution landscape data that has been collected for the entire Earth's surface every 16 days since 1972 (except where there is cloud cover).

The majority of the satellite imagery used in this research was the 1.0 m IKONOS satellite imagery available in the "World Imagery" layer from ArcGIS. Built by the Lockheed Corporation and managed by Space Imaging Inc. (Broad 1999), it was the first satellite to collect publicly available high resolution (1 meter panchromatic and 4 meter multi spectral) data. From its launch in 1999 until being decommissioned by re-entering the atmosphere in 2015, IKONOS provided revisit data roughly every three days (European Space Imaging 2018).

LiDAR data

LiDAR (Light Detection And Ranging), like Radar (Radio Detection and Ranging), is an active sensor that uses laser wavelengths of the electromagnetic spectrum (905 or 1550 nanometers) to measure distances from the sensor. LiDAR is an active sensor meaning that it sends out a signal at a known speed and then measures how long it takes to return. It can be used to generate high density point clouds that can be made into three dimensional reproductions of landscape features (eg: Eldridge and Anaya-Hernandez 2004) collected from the air with planes or drones, or from the surface (Pennanen et al. 2017).

Foresters in Alberta quickly came to appreciate the high resolution 1 meter DEM data along with the ability to measure both the locations of tree tops and the ground surface, which provides an accurate estimate of timber volume in a forest management area (FMA) (Means et al. 2000; Renslow et al. 2000). It was not long after that, that archaeologists discovered that even very small landscape variations were visible in the data and research began on the use of LIDAR landform analysis for archaeological potential analysis (Verhagen and Drăguț 2012, Benson et al. 2003). The 1 m data used here was obtained for the Rangeland Research Institute from Valtus Imagery Services.

Drone Imagery

With the advent of affordable drone technology, archaeologists joined the many other scientists taking advantage of the varied sensors. Cameras were the first and cheapest sensors to be attached to drones and they allow archaeologists to take detailed photos of excavations, sites and even landscapes with precise control over the flight path of the images. Overlapping images, much like those taken in air photo flights, can be stitched together in a large mosaic and offer a detailed image of the ground surface.

Other sensors can also be attached to a drone, including thermal, LiDAR, and multispectral sensors that can provide detailed data for as large an area as a user has time and battery life for. The advantage of the precise control over the data collection must be balanced with the limitations of time and money to process the collected data into a usable form.

Drone images of the known archaeological sites on the Mattheis ranch were collected using a DJI Phantom 4 Pro drone with an attached camera from height of 60 m by Micheal Ma of Western Heritage. The resolution for the data sets at all the sites is less than 5 cm on the ground, capturing detailed images of excavation locations and making individual stones in tipi rings and cairns visible.

The prairie setting made data collection fairly straightforward, as the drone was not flown on a particularly windy the day. The biggest challenge was that of avoiding the electrical transmission lines and towers over the sites when creating the drone flight plans. In the end, the decision was made to fly above the power lines, but it did mean that although the lines were removed from the images as much as possible, they are still visible.

Aerial data comparative capabilities example: Rubbing stone

An illustrative comparison of how the different technologies see the ground surface can be seen in the images captured of the rubbing stone in the northeast corner of the Mattheis Ranch (*Figure 4.1*). Rubbing stones are common in the prairies, where glacial

Figure 4.1: The rubbing stone on the Mattheis Ranch as seen in 2019 on the left, and as seen in its depression on the right. Note the polished peak of the stone in the photo on the left.

erratics were deposited on the prairie surfaces, and used by bison to rub off winter coats or scratch itchy bug bites in summer. They are identifiable by a smooth, polished rock surface and the depression of the soil surrounding the base of the stone where hooves disturbed the soil, allowing it to be blown away (Neufeld 2012).

The rubbing stone is not visible in the 1952 air photo (*Figure 4.2*) but, given that the photos were flown at an altitude of 23,000 feet, the resolution isn't nearly good enough to expect to be able to. We do know it was there at the time though, because Edwin Mattheis said it was already there in the 1960's when he and Ruth bought the ranch (Ives 2019, personal communication).

The stone is visible in the ArcGIS World Imagery data that has a resolution of roughly 15 cm per pixel, as a bright spot on the landscape (*Figure 4.3*). The LiDAR shows a slight depression in the area of the rubbing stone, which is accurate given that it sits in a bowl about half a meter deep, but the rock itself is not discernible. It does give an elevation value for the stone and surrounding landscape though.

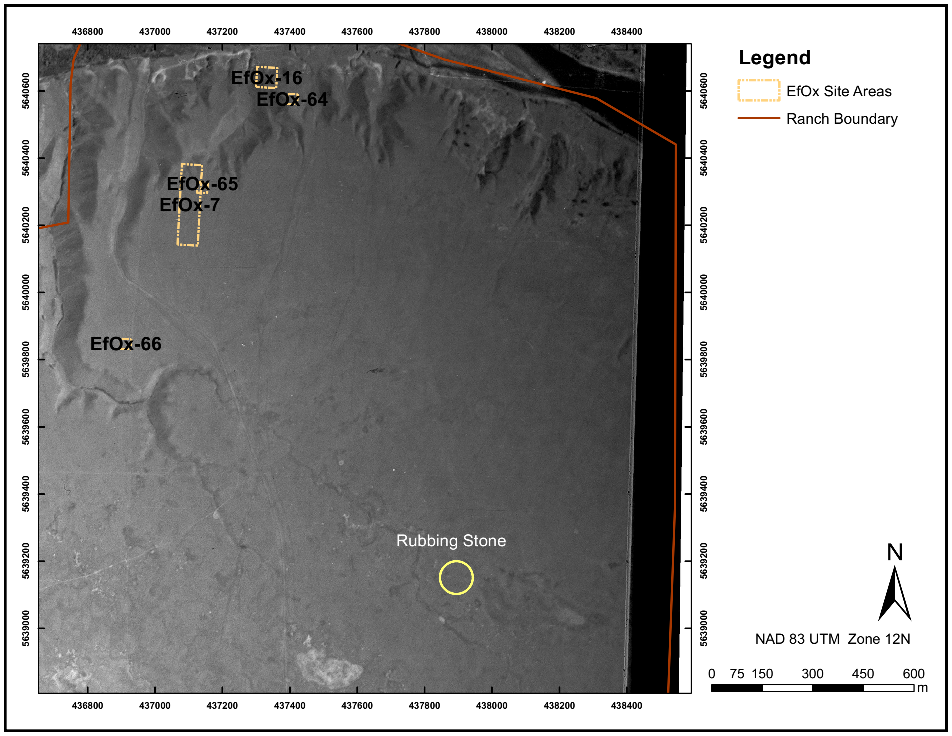


Figure 4.2: Location of the rubbing stone on the 1950s air photo in relation to the Red Deer River, EfOx-66, EfOx-7, EfOx-65, EfOx-64 and EfOx-16, and the northern and eastern borders of the ranch.

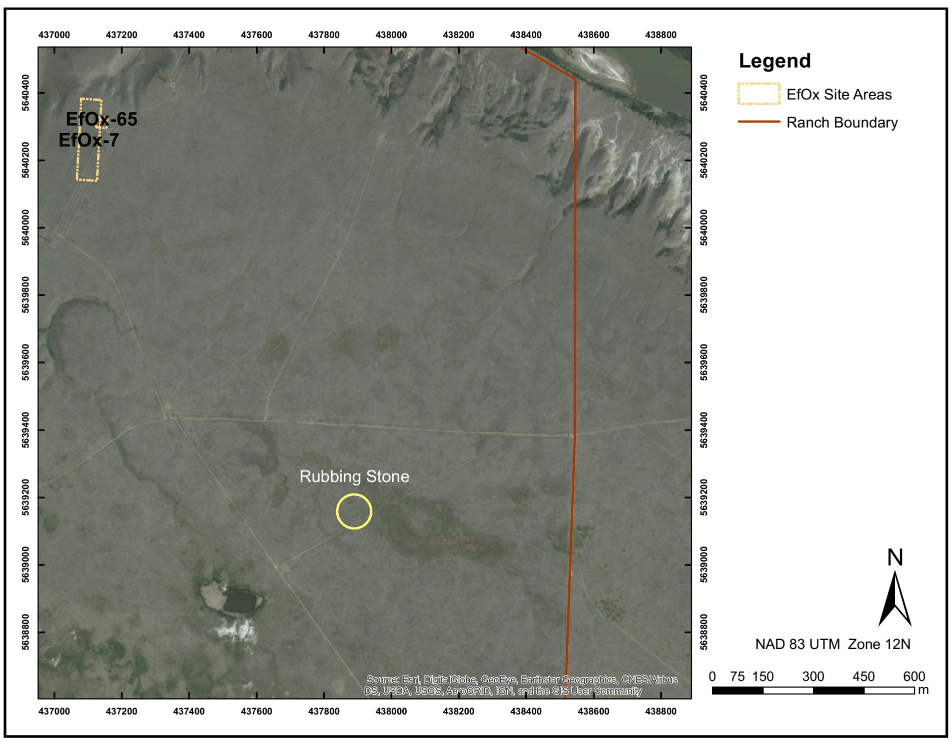


Figure 4.3: Location of the rubbing stone on the modern satellite imagery in relation to the Red Deer River, sites EfOx-7 and EfOx-65, and the eastern border of the ranch.

Figure 4.4: Satellite imagery (top) and drone image (bottom) of the rubbing stone showing the difference in the resolution of the imagery data. Note that the drone data shows the depression surrounding the stone and the vegetation difference.

The drone data has a resolution of 0.00514 m (0.5 cm) per pixel and here the shape of the rock and it's depression can be seen. *Figure 4.4* compares the stone's visibility in the drone data to the same scale in the satellite imagery.

This shows the various strengths of the technologies and what can be learned from them. The historic air photo gives a good general overview of the ranch landscape in the 1950's, but does not help as much with archaeological features that are generally only a few meters in size. The LiDAR data provides elevation data for the depression it sits in and the surrounding prairie. The satellite imagery shows that something highly reflective that is about 1 to 1.5 meters in size is there, but it is only the drone data that gives a clearer image of the stone itself.

Aerial Data are a good example of why remote sensing is not generally looking for artifacts. Sensors can not get close enough to see at an artifact scale but much can be learned at a feature or landscape scale. On the Mattheis Ranch aerial data provided insight into potentially culturally relevant landscapes including the wetlands west of the ranch, the Matzhiwin Creek drainage, and the Red Deer River Valley.

Wetlands

The wetlands were built up by Ducks Unlimited Canada on the area between the two lobes of the Duchess sand dunes that is predominantly "of ice-contact glacilacustrine and glaciofluvial deposits up to 25 cm thick…" (Wolfe et al. 2002: 2). Before that work the wetlands were seasonally dry, but the satellite data and the historic air photos show that the wetland area still offered a topography that is significantly different from the hummocky terrain in the sand dunes surrounding them.

While harder to see in the black and white air photos collected in early 1950's (*Figure 4.5*), the wetlands area is greener than the surrounding dunes, with most areas

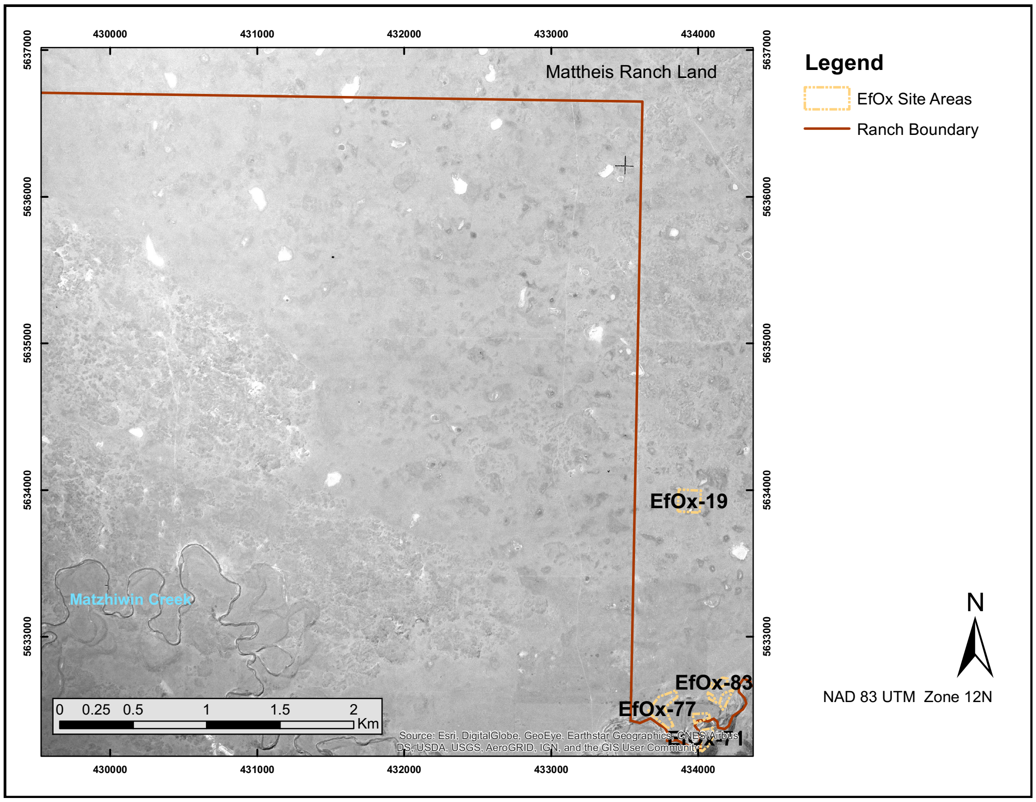


Figure 4.5: While difficult to see in the 1950's air photo, the hummocky terrain of the sand dunes in the west side of the photos is still distinct from the flatter area where the wetlands will be. The darker patches in the wetlands area suggest that even before they were dammed, this area was greener.

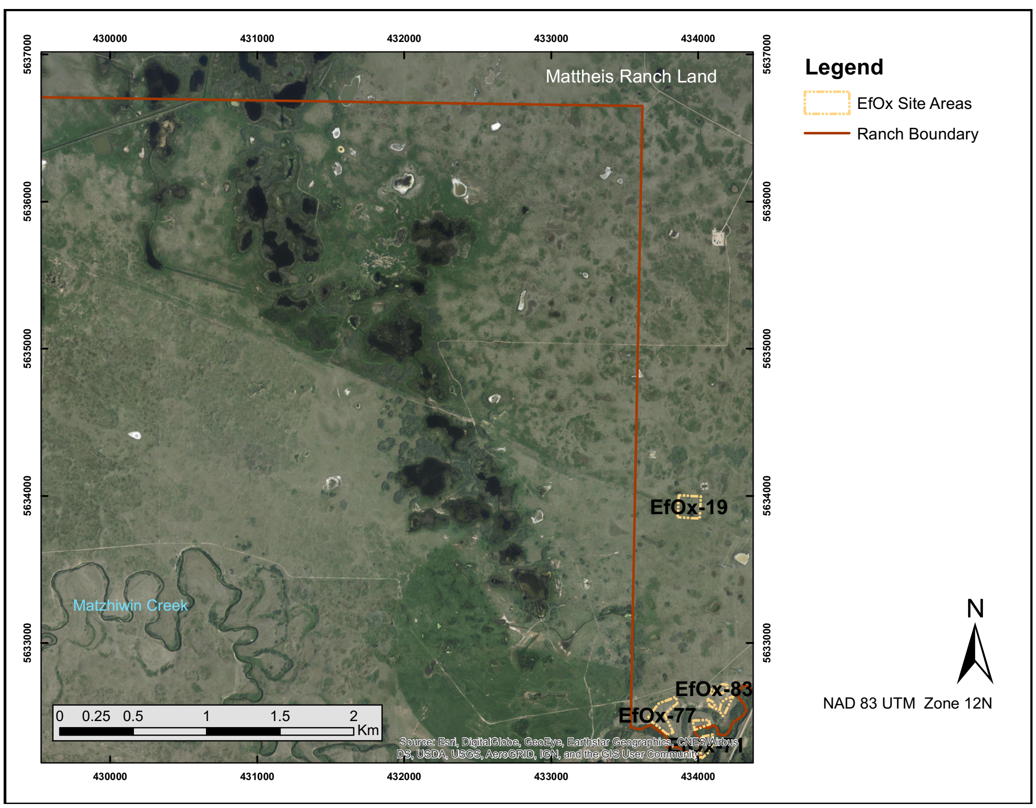


Figure 4.6: Note the edges of the hummocky terrain in the satellite imagery, and the green vegetation surrounding the wetlands.

Figure 4.7: Silver buffalo berry bush on the Mattheis ranch on the north side of Matzhiwin Creek in 2018.

of greener vegetation even maintaining the same shape in the satellite images captured more than 50 years later (*Figure 4.6*). They also show the beginnings of where the water would collect after the Ducks Unlimited work in the form of highly reflective salt flats that likely collected water during spring runoff then dried out in the summer.

There is now definitely more vegetation around the Ducks Unlimited wetlands than in the dunes. The darker patches in the 1950's air photos wetlands area suggest that even before they were dammed, this area was greener. Since the creation of the wetlands more salt tolerant shrubs like Silver Buffaloberry (*Shepherdia argentea*) have grown up (*Figure 4.7*).

This wetland area might have had a natural appeal to bison as there were likely better grasses here than in the sand dunes because water would collect closer to the surface. There was also likely better footing than in the hummocky sand dunes. If herds naturally congregated here, it would be a natural collection point for hunters hoping to drive them into a trap down in the Matzhiwin Creek valley as discussed later.

Matzhiwin Creek

When standing at the top of the Matzhiwin Creek southern upper valley margin overlooking EfOx-70, there is an obvious prominence connected to the valley wall that seems to have once connected to a pointed prominence on the north side of the creek almost directly west of EfOx-71 (*Figure 4.8*). A hill shade display of the LiDAR DEM data shows the point on the north side of the creek very clearly and the prominence on the south side of the creek can be easily made out as well (*Figure 4.9*). What is most interesting is that the LiDAR data also clearly shows a relict stream channel that apparently forced the water north, around the point that is visible today.

It is likely that these two prominences are outcrops of better compressed and harder to erode Empress formation gravels (Barling 1995) that were connected in the past, giving the creek valley an even more of a bowl shape than it currently has. Given that the dates of the bones found at EfOx-70 and 71 are in the 1300 to 1200 year BP

Figure 4.8: Looking east-southeast across Matzhiwin Creek at the matching prominences with the Creek running between. (Photo by Dale Fisher)

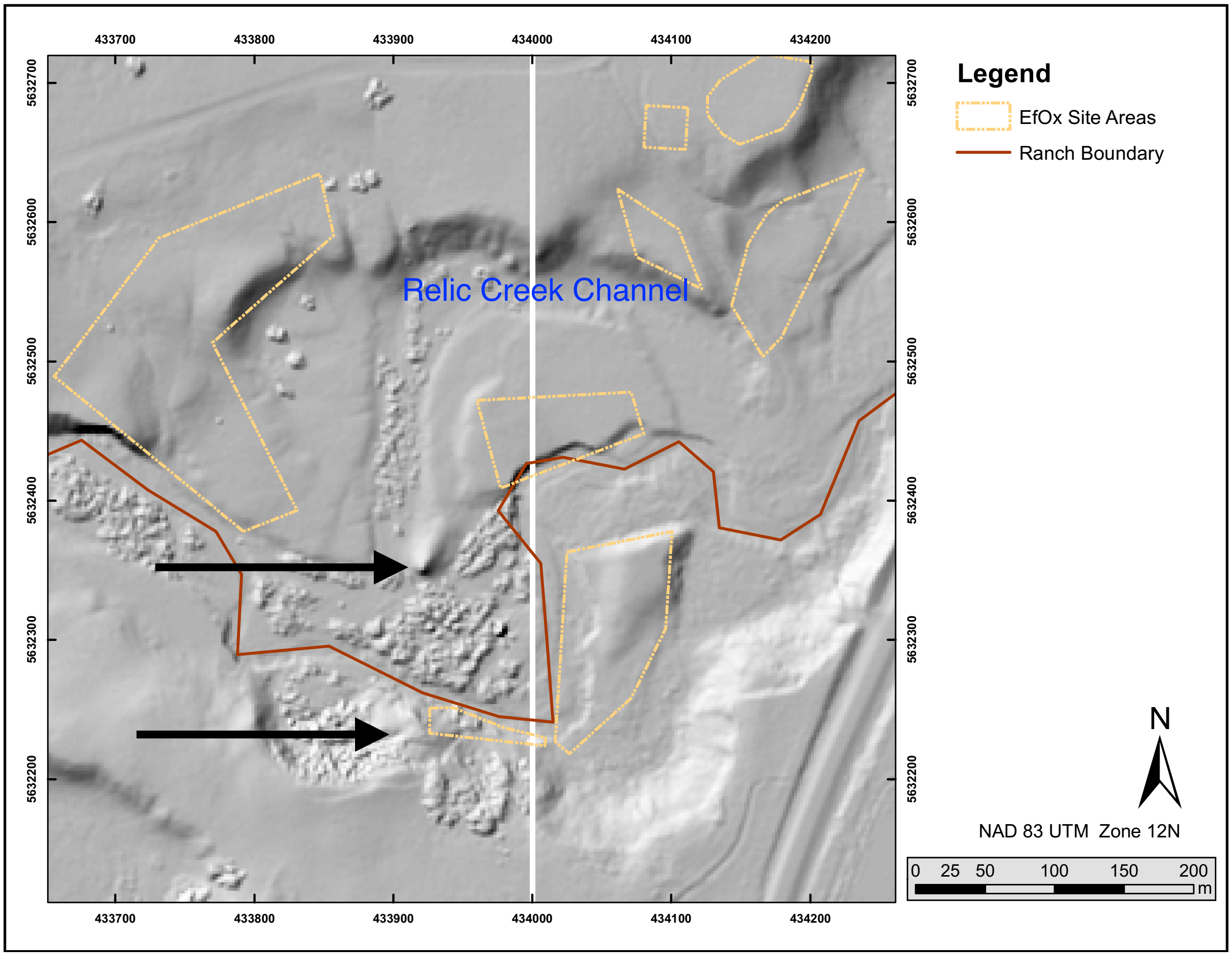


Figure 4.9: Hill shade of Matzhiwin Creek area that shows the prominences on either side of the creek and the relic stream channel. The current channel roughly follows the Ranch Boundary line.

range (Ives et al. 2020), it is possible that at the time of site use, the creek still flowed through the northern channel and did not break through until a period of incising 800 to 300 years before present (BP) (Barling 1995).

The relict stream channel point on the north side of the creek can also be seen clearly on the satellite imagery data. The edges of the stream channel can be seen in the prairie elevation change and the brush that has grown up in this lower area that now traps the water flowing off the surfaces above it on all sides. The prominence coming out of the south side of the Matzhiwin Creek valley is a little harder to see, as it is surrounded and partially covered in trees and brush. It is noticeable, though, as an indent of the prairie surface creating an edge to the treed creek valley margin that creates a distinctive bowl on the south side.

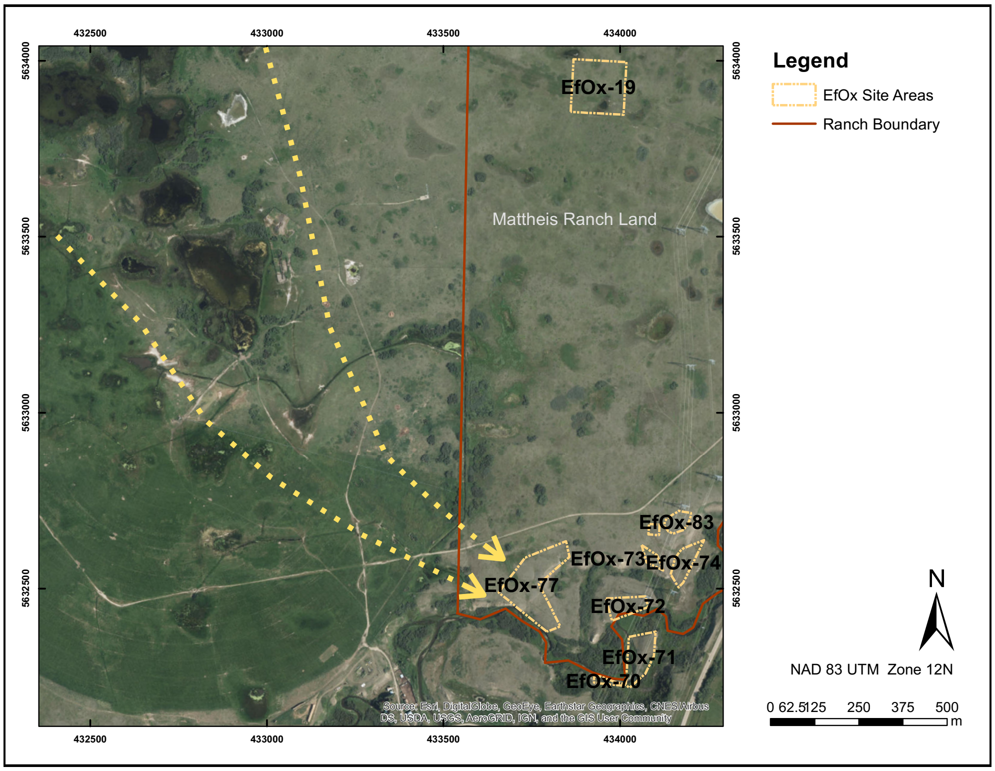
This landscape offers three possibilities for the use of the Matzhiwin Creek area that will be briefly discussed here as Fisher 2020 (153-169) offers a more complete discussion. The focus here is on the technology used to develop the theories and how those tools suggest avenues for further research.

Theory 1: The Northwest Entry

The first theory (Scenario 2 in Fisher 2020: 158) is suggested by the satellite images and the edges of the available airborne LiDAR data. As shown in *Figure 4.10a*, there is a smooth, almost funnel shaped, swath of land between the dune lobes that runs from the Ducks Unlimited wetlands in the northwest down towards EfOx-77 in the southeast. A gentle slope down the southern arm of the EfOx-77 archaeological site in *Figure 4.10b* allows access into the creek valley that is still used by cattle today. It is only about 1 km from the southernmost wetlands and once in the creek valley, bison would have been corralled by the steep slopes of the creek valley to the north and south. From there the animals could be further corralled towards the cliff edge south of EfOx-70 and EfOx-71. This landscape offered all the requirements of an effective trap (Frison 1998) with a natural gathering place for the bison; an area of low relief that would allow entry to the trap; and a steep sided area where bison could be trapped, surrounded, and killed.

There is a small rock cairn on the bank of Matzhiwin Creek that looks like it may have been part of a drive lane, but its proximity to the current fence line makes it

(A)



(B)

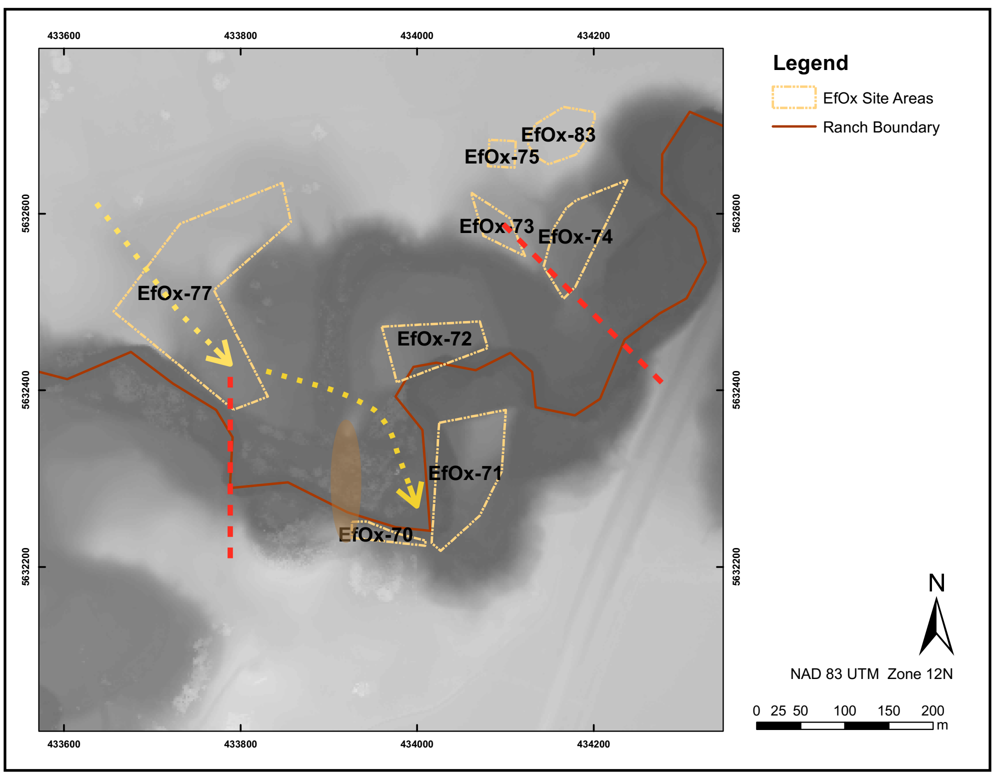


Figure 4.10: (A) Satellite imagery showing the possible path of the bison drive into EfOx-77 from the wetlands. (B) Digital elevation model showing the potential incoming path of the bison drive and the bowl (dark areas) created by the creek valley with the pinch points in red.

suspicious (*Figure 4.11a*). A foot survey of EfOx-77 in 2017 found another partially buried possible cairn on the incline down to to Matzhiwin Creek (*Figure 4.11b*). Nothing further was found northwest of EfOx-77, but the land beyond the ranch fence line was not surveyed.

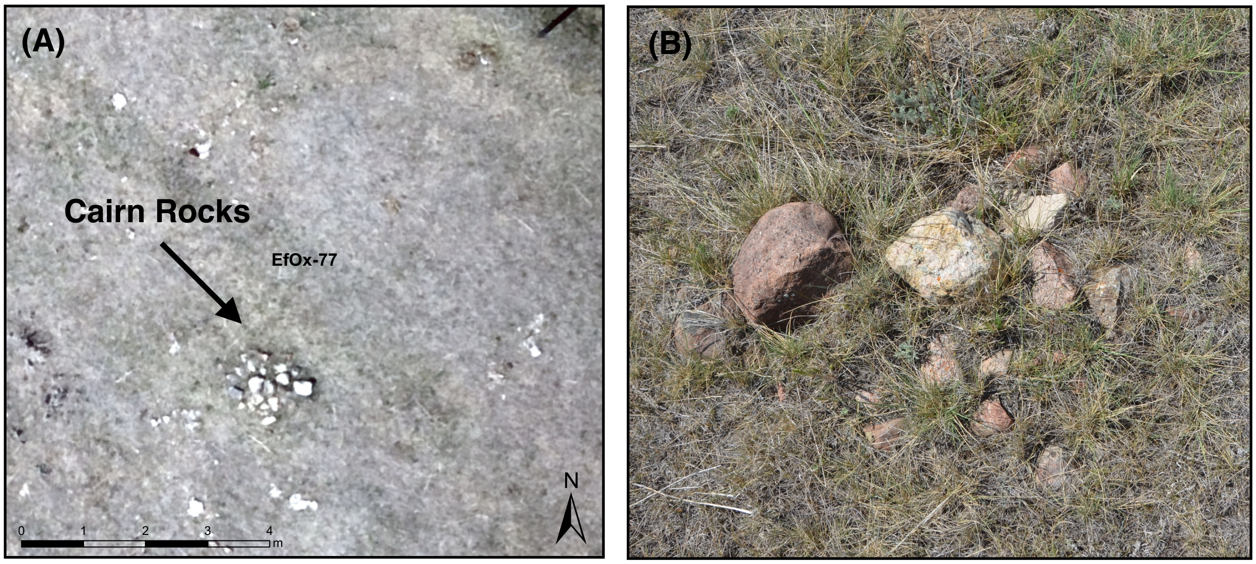


Figure 4.11: Cairns identified at EfOx-77. (A) Drone image of the cairn south of the Mattheis Ranch southern fence at the bottom of the decline into the creek valley. (B) The second cairn located at the top of the decline, a few meters north of the Mattheis Ranch southern fence (Photo courtesy of Dale Fisher).

Theory 2: The Jump

A second theory (Scenario 1 in Fisher 2020: 158) is that bison were collected from the plains south of Matzhiwin Creek and run north to use the southern river valley margin as a jump. While there is no evidence of drive lanes known currently, they may have been lost to agriculture or the development of the highway and transmission lines. Satellite imagery (shown in *Figure 4.12*) and the airborne LiDAR digital elevation model of the area show several areas along the southern valley margin of Matzhiwin Creek that are steep enough to drive bison over (ie: drops of 10-20 meters or more), including the margin south of EfOx-70 and EfOx-71. Excavations at EfOx-70 in 2019 (Fisher

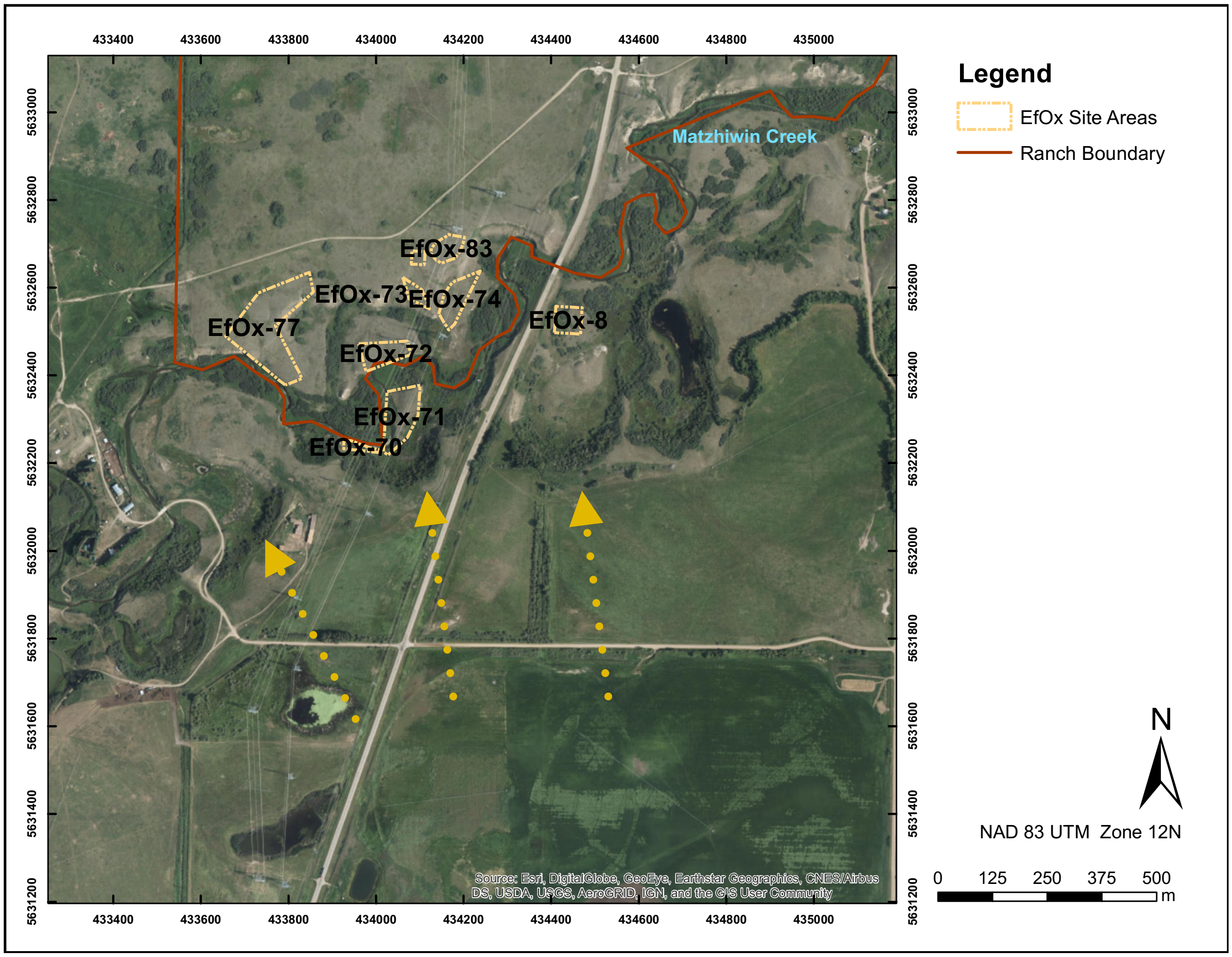


Figure 4.12: Other possible jump locations when driving bison north from the prairies south of Matzhiwin Creek.

2020) and the soils there (discussed in further detail with the GPR results in chapter 6) both point to this location as the initial butchering site. This would make sense if bison were landing at the cliff base and initially being butchered there to be removed to the area of EfOx-71 and EfOx-72 where there was space for further butchering and processing for meat, marrow and hides.

There are several areas nearby that offer good jump locations with the necessary cliff height and space below to process the animals. Testing at the base of the upper valley margins south of EfOx-8, now east of AB Highway 36 might provide more insight into how people were using the natural landscape here as that site is east of the natural nick point suggested in the first theory. Evidence of initial butchering areas at the base of the cliffs and processing areas out around EfOx-8 would suggest that the area is being used as a jump rather than a trap.

Theory 3: The Western Stream Bed Entry

A third theory (Scenario 3 in Fisher 2020: 162) is that the bison were herded east through the creek valley where they would have naturally gathered, along the edge of EfOx-77 (*Figure 4.13*). This theory assumes that the bison would have already been

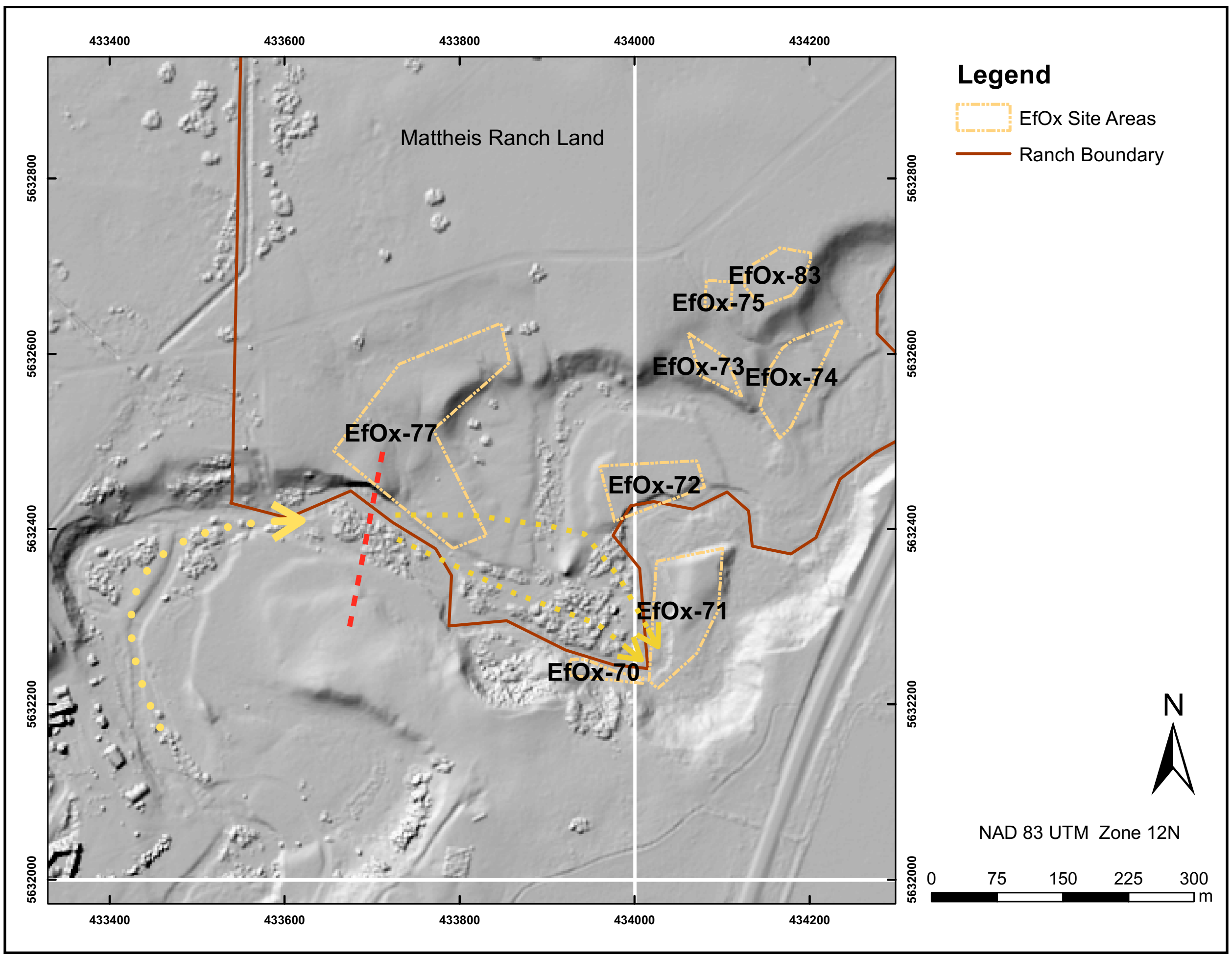


Figure 4.13: Hill shade of the airborne LiDAR showing the entry into the bowl of the trap and the pinch point of the valley before the opening into the bowl.

drawn to the water and riparian environment of the creek valley (Fisher 2020) and could be pushed west into a trap area similar to the first theory.

The challenge in determining which theory of how the area was used is accounting for the effects of erosion on the creek valley. A comparison of 1950s air photos and current satellite imagery of Matzhiwin Creek shows that the area of erosion just in the area between EfOx-70 and EfOx-71 caused by the movement of Matzhiwin Creek is over 900 m^2 (*Figure 4.14*). The whole valley is missing information that ties the larger site area together that has been washed downstream.

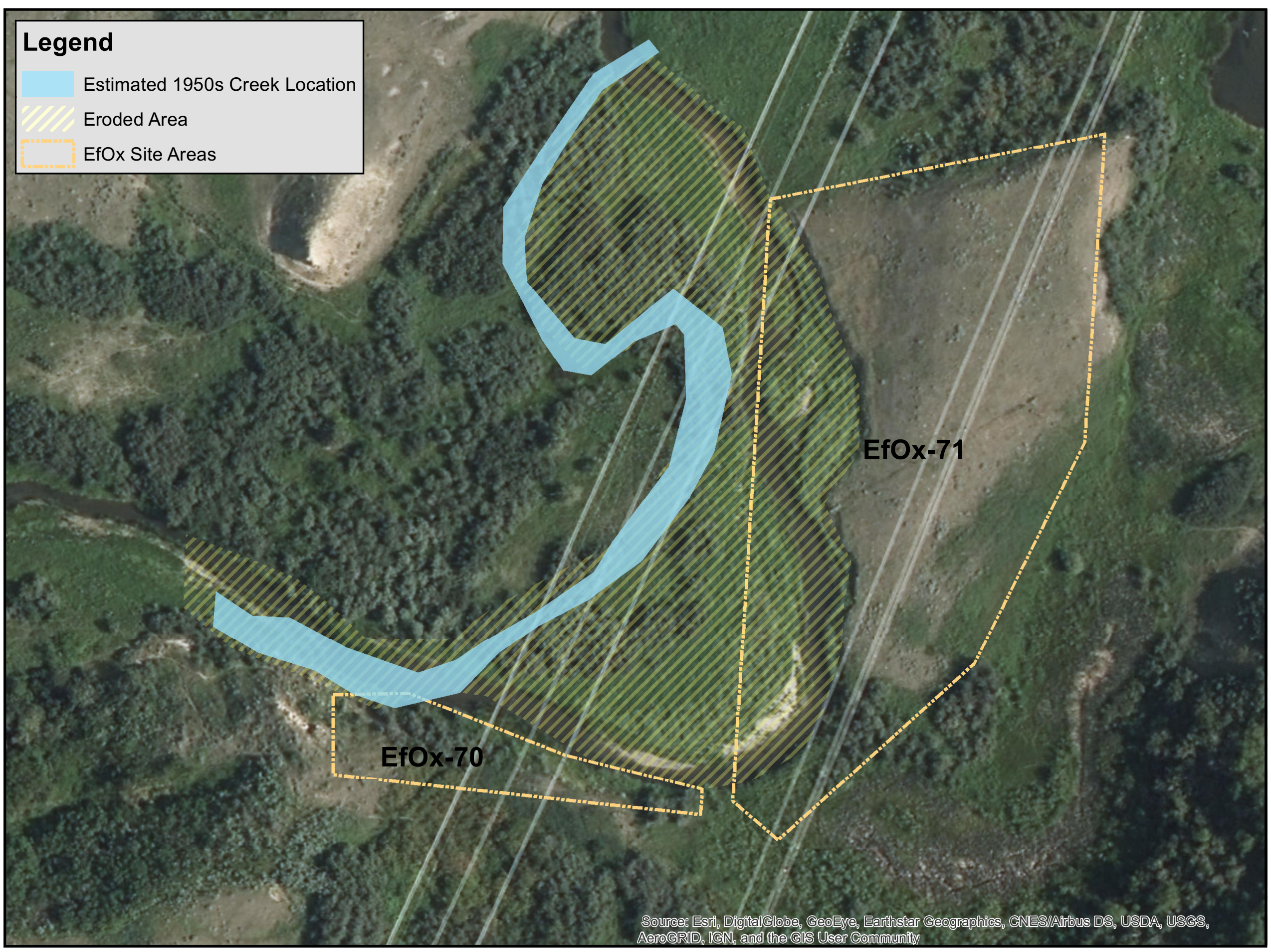


Figure 4.14: Comparison of the 1950s creek location around EfOx-70 and EfOx-71 according to the air photos, to the its current position according to satellite imagery and the eroded area in between.

Red Deer River

At the archaeological sites along the Red Deer River, drone data that was collected at each of the EfOx-59, EfOx-80 and EfOx-81 site locations proved to be the most informative. In the case of EfOx-59, drone data was collected not where the geophysical data was collected and excavations carried out, but at the actual site location in the hopes of relocating the tipi rings reported in 2006 as shown in *Figure 4.15*. The bright, sunny weather conditions while the data was collected made many of the surface rocks highly visible in the images, but the rings at EfOx-59 could not be relocated. They may be completely overgrown by now, or they may have been disturbed by cattle or vehicles working in the field.

Figure 4.15: Drone Imagery of EfOx-59 recorded site area.

The ring that was documented by the archaeological field school students in 2012 at EfOx-80 is clearly visible in the drone data at a scale of 1:100 (Ring 1 in *Figure 4.17,* next page). Other rings were recorded at the time, but their mapped locations are not clear in comparison to the collected drone data. Examination of the drone data revealed other possible targets, two of which are shown along with the clear surface ring in *Figure 4.17*.

At EfOx-81, a partial ring recorded by the 2012 field school students is visible in the drone data (*Figure 4.16*). No other features can be found in the the drone images, and this was corroborated by a second walk-over by field school students in 2019 when more faunal artifacts and FCR were observed, but no additional stone rings.

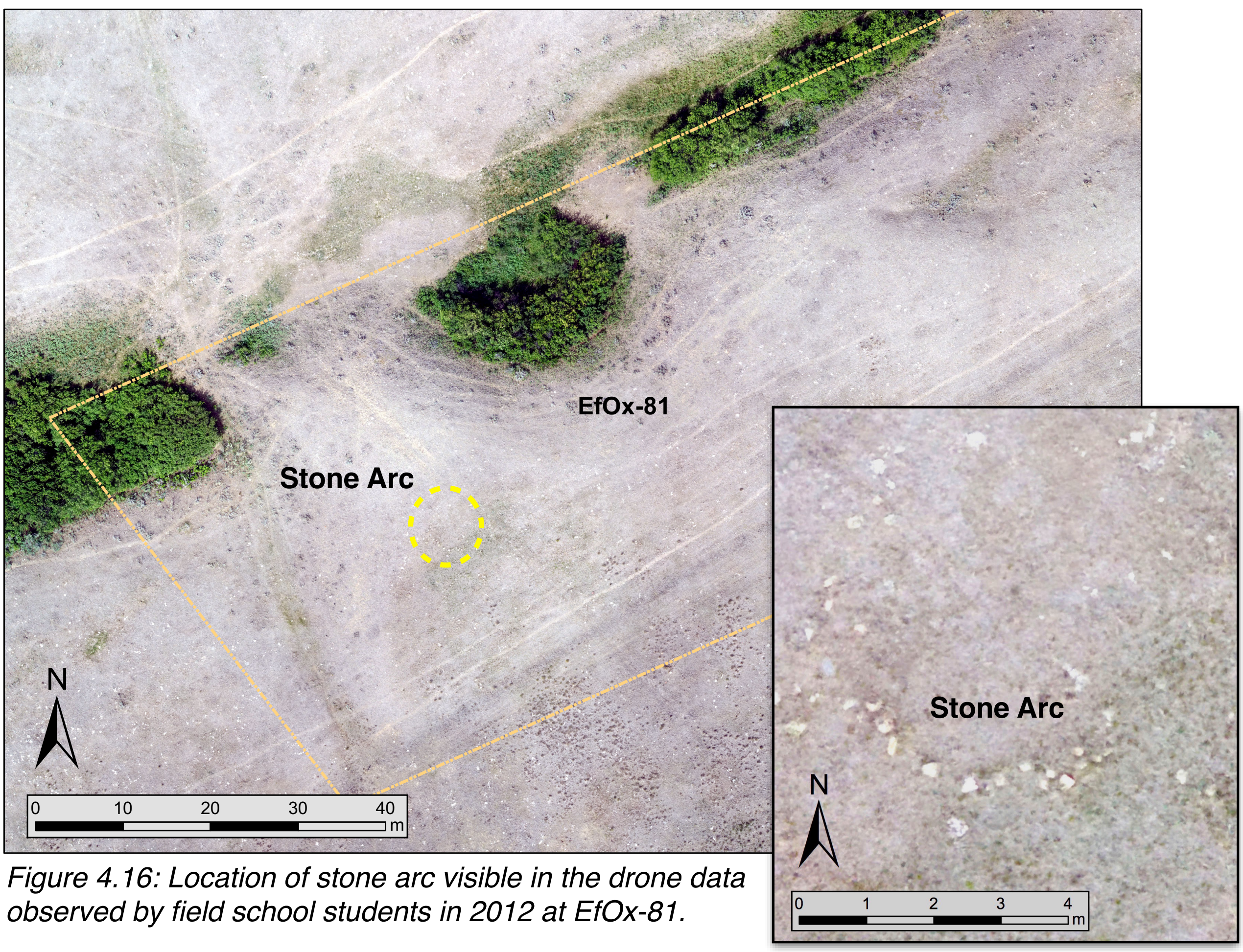
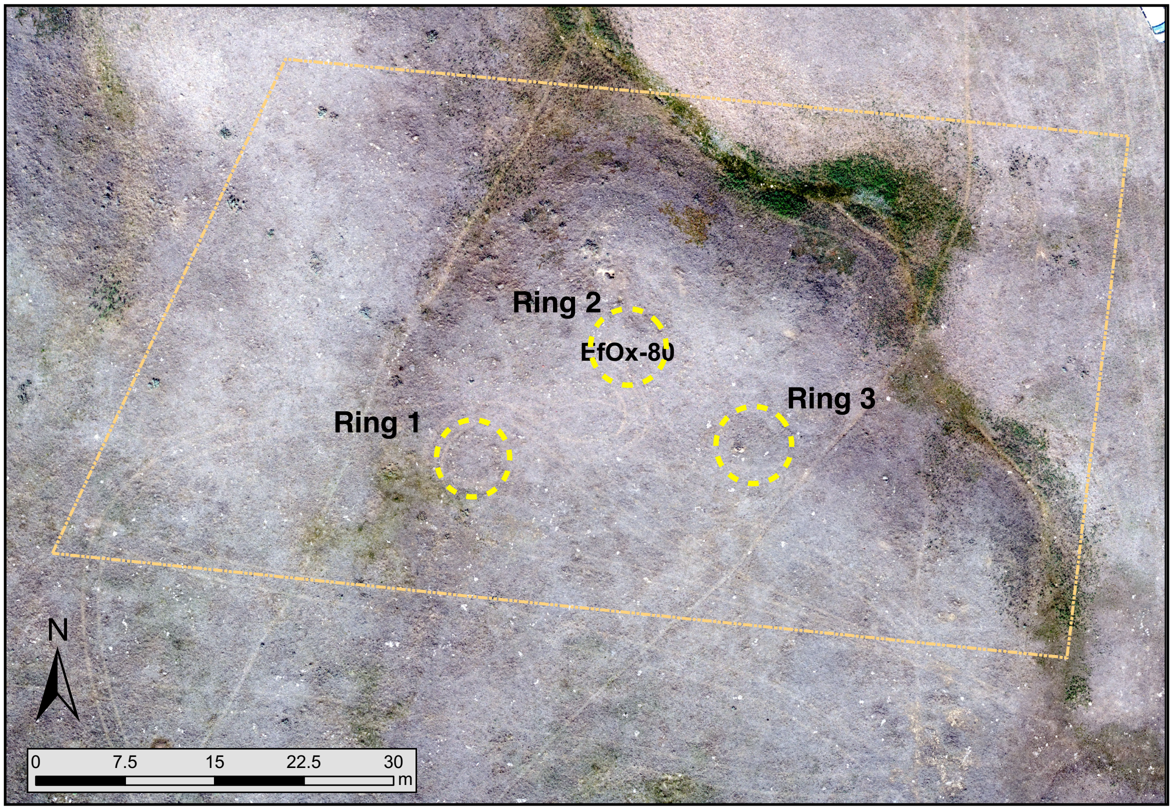
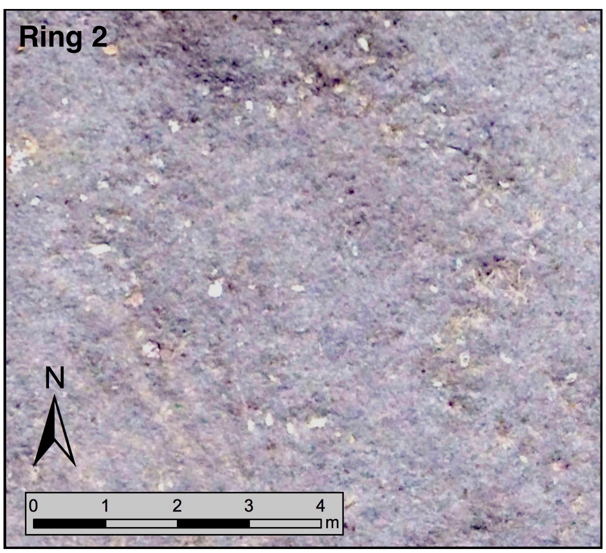
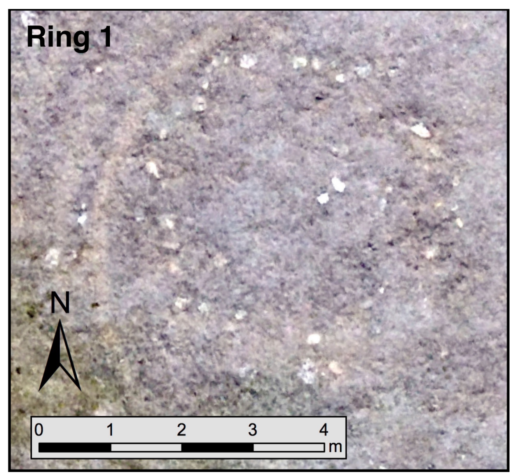


Figure 4.16: Location of stone arc visible in the drone data observed by field school students in 2012 at EfOx-81.







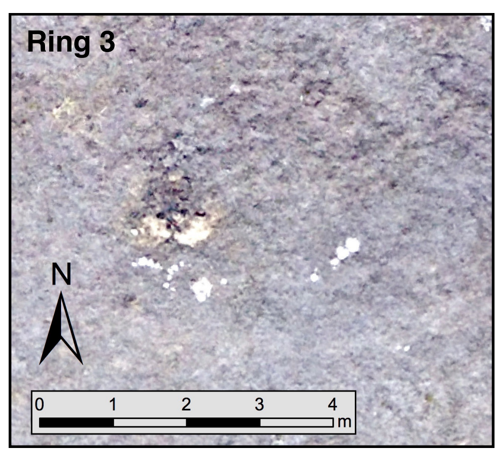


Figure 4.17: Locations of three of the rings visible in the drone images within the EfOx-80 site location circled (top) and detailed images of the noted rings (bottom three insets).

The area that is now the Emerson Bridge Park makes an excellent natural corral for horses (*Figure 4.18*). The northwestern edge of the park has a beach that allows easy access to the river for water and the valley vegetation provides forage and shelter. The 1950's air photo shows that the southern parts of the park, closer to the cliff, were vegetated but the northern area next to the water looks like sand or grass (highway 36 and the campground are not there yet). If the treed area next to the river is more recent, as the air photo suggests, the top of the river valley margin might have been a good place to watch over the herd. Even if the location was more treed than the prairie above,

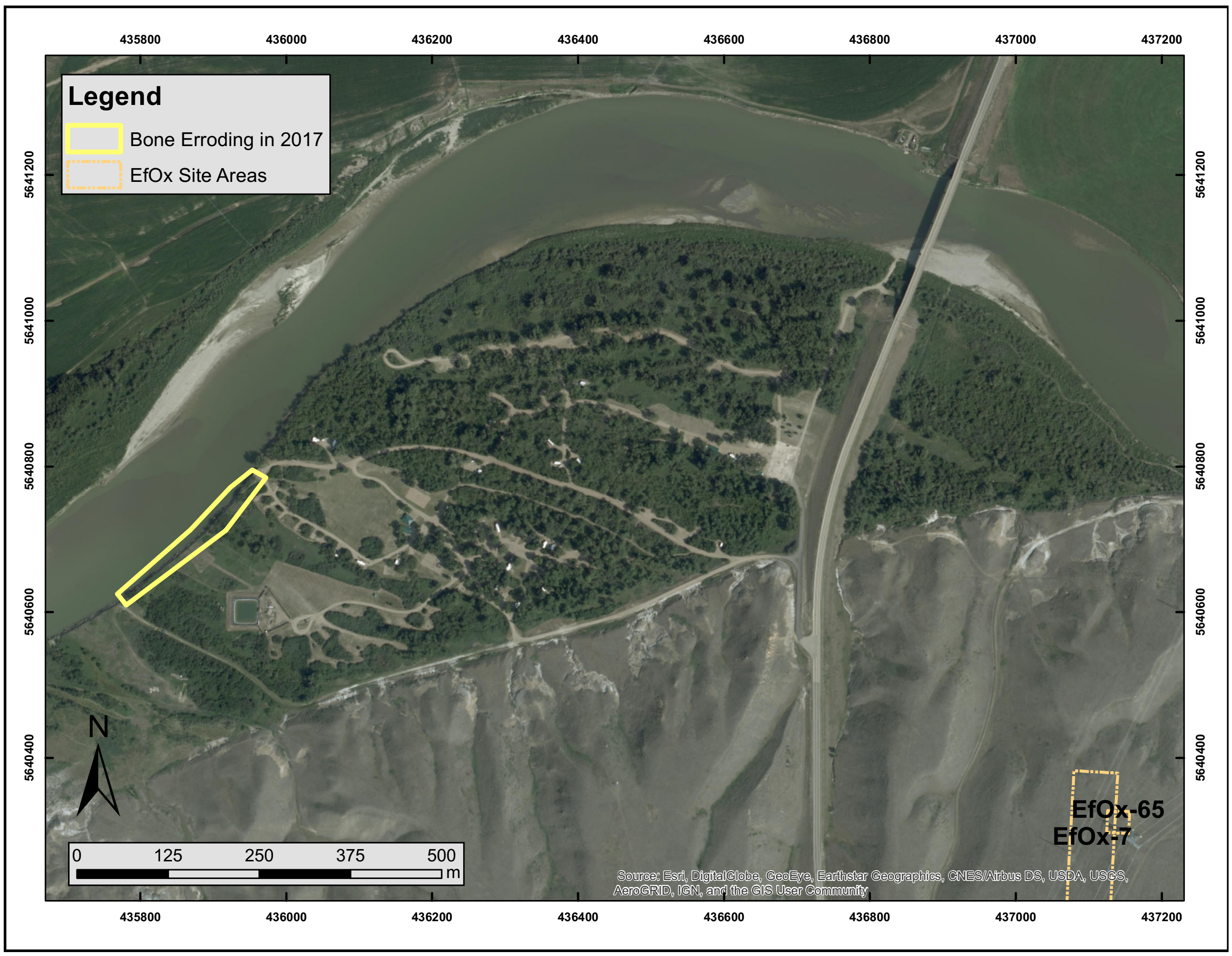


Figure 4.18: The Emerson Bridge Park on the northern edge of the Mattheis Ranch and the location of the eroding bones observed by Dale Fisher in 2017 and 2018.

the location would have made a good winter camp, providing shelter and fuel along with forage for horses.

There was a site observed in the cut of the riverbank on the western edge of the campground in 2017 and 2018 that contained bison remains. By 2019 the site was eroded away by high river waters and the remaining bones were resting on the eroded soils of the riverbank, but it still shows occupation of one of the lowest river terraces at some point in time. Many of the same assets the area held for horses would also have been applicable to bison herds in the more distant past.

Aerial Data Conclusions

The topography of the northwestern plains, and specifically of the Mattheis Ranch offers some unique opportunities that can be taken advantage of by those prepared to do so (Oetelaar 2014). Generally, for this project, aerial data was used to give a landscape scale context to the archaeology, giving insight into what makes the locations of sites desirable to people for different purposes.

At Matzhiwin Creek, the combination of satellite imagery and available airborne LiDAR DEMs provide testable theories of how the landscape was being used by bison hunters. The comparison to modern satellite images provided by historic air photos collected in the 1950s offers an indication of how the vegetation has changed and an erosion analysis that can be expanded along Matzhiwin Creek both up and down stream, giving a record of the effect of erosion on the EfOx-70 and EfOx-71 sites.

Having detailed satellite images of the sites, especially along the Red Deer River, gives a visual reference for where sites are on the land, and how they relate to each other. For those who have never been to a site like EfOx-80, the imagery gives a clear understanding of details like the grassy location and its proximity to other sites and to the Red Deer River. The satellite images also display the appeal of the Emerson Bridge Park as a natural corral for horses or a draw for bison herds.

The drone data proved to be especially useful in providing enough detail to look for stone rings and cairn features. Along the Red Deer River upper valley margin, drone images were shown to make mapping tipi rings on the landscape easy. This has led to a still in progress[2] experiment in image classification and infrared imagery collection to see if even rocks that do not reflect light as well or that are hidden by long grasses can still be mapped. Along Matzhiwin Creek, two cairn features are visible on the landscape and a low altitude flight towards the wetlands from EfOx-77 could provide evidence of more cairns and possible drive lanes from that direction.

Overall, the usefulness of the different data types depends on the landscape research questions. Here they have offered a way to look for previously unrecognized or unmapped features. They give an important insight into how the landscape may be used and allow archaeologists to look at the relationships between archaeological sites that would not be possible without this bird's-eye view.

To gain an even more in depth look at the features on the ground and even below it, near surface geophysical techniques of magnetometry and GPR were employed.

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[2] Results of this project undertaken by Western Heritage and the Rangeland Research Institute are expected to be ready for review in the winter of 2021/2022.

Chapter 5 - Magnetic Gradiometry

> “Magnetomery surveys are probably the most productive prospecting method employed in archaeology; it is almost as if nature designed archaeological sites to be made visible by the magnetic anomalies within archaeological sites.” (Kvamme 2003: 441)

How Magnetometry Works

Magnetometry takes advantage of minute differences in the electromagnetic field generated naturally by some materials, or those that are heated beyond the Curie point, the temperature above which certain materials lose their permanent magnetic properties to be replaced by induced magnetism. In pre-contact archaeology, this change in the magnetic field is frequently caused by firing of the soil or accumulations of fired artifacts (such as hearths, fired rocks and pottery), but it can also be generated naturally by stones used in construction, or the decay of heavily organic layers of soil. Of course, where metal is present, iron and other ferrous artifacts are also easily picked up by magnetometry equipment, potentially at a greater depth than with a metal detector.

Kvamme (2003: 441) outlines 8 phenomena that contribute to magnetic anomalies in archaeological sites:

1. Firing the soil beyond the Curie point.
2. Accumulations of fired artifacts.
3. Variations in soil and sediment magnetism due to composition and/or exposure.
4. Natural processes that change magnetic properties of surface soil layers; extended human occupations generally exacerbate this effect and paleosols tend to retain it.
5. Removal of magnetically enriched topsoil during construction or excavations causes a lowering of the magnetic field over these features.
6. Accumulations of topsoil creates local increases in the magnetic field.

7. Rocks that might be employed in the construction of buildings or pavements might be more or less magnetic than surrounding soils.
8. Iron or steel artifacts markedly alter the earth's magnetic field, producing readily sensed anomalies and large magnetic measurements commonly expressed as dipoles consisting of paired positive and negative extremes at mid-latitude

Several of the phenomena listed by Kvamme can immediately and easily be applied to several types of European and post European contact North American sites. Sites that contain a lot of pottery and kilns such as Medalta Potteries in Medicine Hat would offer rich fodder for magnetometry, as would buildings with stone or brick foundations. Earth works have been extensively mapped with magnetometry in Europe and in North and South America (Schroeter, J 2017, McLeester & Schurr 2020 for example).

Magnetometry has been used on the Northern Plains in a pre-contact context in Canada since at least the early 1980's when Gibson (1986) did a survey of a precontact Cree campsite next to the North Saskatchewan River near the town of Nipawin, Saskatchewan. Since then, its use has waxed and waned, but there has been a renewed interest over the last 10 years or so in Alberta as result of developments in the instruments and an increased understanding of the technology by more archaeologists. This is reflected in the use of magnetometry data by consultants contracted by the Heritage Resource Management Branch of the Alberta government in some of the assessment work done after the 2013 floods in southern Alberta (Roe et al. 2017, Gibson 2017).

This research aims to take advantage of three (specifically numbers 1, 2 and 7) of Kvamme's phenomena by examining whether tipi rings, hearths, or other campsite features might be “visible” to these technologies that may not be visible on the surface. If hearth features have been used repeatedly for cooking or heating they are likely to have changed the magnetic properties of the soil, and Gibson’s experiments in the 1980’s showed that only one firing was required to change the magnetic properties of rocks (Gibson 1986). Hearths are often the centre of activity in a living space, whether they are used for cooking, heating or light, and are therefore central to the understanding of site use.

For the sites in this project, hearths, whether they are inside or outside known tipi rings, should be “visible” in the magnetometry results, giving insight into the overall camp make-up. The results will depend somewhat on how long people were staying in an area, as a lasting magnetic signature is more likely to be created when fires are burned repeatedly in one place over longer periods of time (Gibson 1986).

Tipi rings are also potential targets if the rocks employed in holding down the lodge poles and hide covers have a magnetic field different enough from the surrounding soils, or if the soils have been altered enough through habitation to be more organic then their surroundings.

Magnetometry Methods

Magnetic data was collected over three summers from 2017 to 2019 with a Gem Systems GSM-19 Overhauser Magnetometer using the walking gradiometer set up. Each collection point was automatically recorded with a GPS point location. Data collection was done in grids with lines separated by 50 cm with a cycle rate of 0.5 or 0.2 depending on the year it was collected (0.5 in 2017 and 0.2 in 2018 and 2019). Grids were set up to cover the most area possible of the natural landscape, so they were generally lined up along terrace or coulee edges. In the case of Area C at EfOx-77, the grid was long (50 m) and skinny (only 15 m wide) to fit between a barbed-wire fence and the bank of Matzhiwin Creek.

The collected gradiometry data tables were then cleaned up to remove erroneous data points and the point location tables were prepared for use in GeoSoft Oasis Montaj. Experimentation with several methods of data processing showed that too much smoothing of the data removed too many of the subtle anomalies being tested for, so a minimalistic approach was settled on. Imported gradiometry data points were converted to a grid using a Kriging method and then displayed using a normal distribution of the collected gradiometer nT/m (nano teslas per meter) values.

In Area A of EfOx-77, a polynomial filter with a trend order of 1 was also used to smooth out the data across the four grids that had been collected over one day in 2018 and three days in 2019. The smoothing made the data comparable across all the collection grids.

Although GPR and UAV data were collected at EfOx-70 and EfOx-71, magnetometry data could not be collected because there are two sets of electrical transmission lines that were shown to seriously affect the magnetic readings within about 100 m of them. EfOx-70 is between the two sets of lines that are roughly 50 m apart, and EfOx-71 is directly under the eastern-most lines.

Magnetometry Results along the Red Deer River Valley

The archaeological sites of on the Mattheis Ranch along the upper valley margin of the Red Deer River valley are all tipi ring sites identified either as part of Historic Resource Impact Assessments for a well site (EfOx-59) or by the archaeology field schools held in 2012, 2017 and 2019 (EfOx-80 and EfOx-81) by the University of Alberta Institute of Prairie Archaeology. None of these sites have any dates associated with them as no diagnostic artifacts have been collected and no dating done, only the rings identified and mapped (de Guzman 2006; Ives et al. 2020).

EfOx-59

The magnetometry grid for EfOx-59 was actually placed northwest of the recorded site location as shown in *Figure 5.1*. Three tipi ring features recorded at the site in 2006 could not be relocated, though they were described as being “moderately” to “well-defined” with “well-buried” lichen covered stones (de Guzman 2006). This may be due to vegetation growth over the stones or disturbance from cattle grazing the field. These possibly buried stone rings would have been a perfect target for geophysical techniques, but the target area could not be narrowed down enough in the field based on the original site form.

Some possible rings were observed about 125 meters to the northwest of the well pad associated with the discovery of EfOx-59, so the decision was made to set up geophysical grids over these features to take a look at whether the arcs of rock being observed were actually rings or if they were formed by the erosion of the valley edge exposing the glacial till. The magnetometry data, collected in 2018 in a 60 m by 30 m

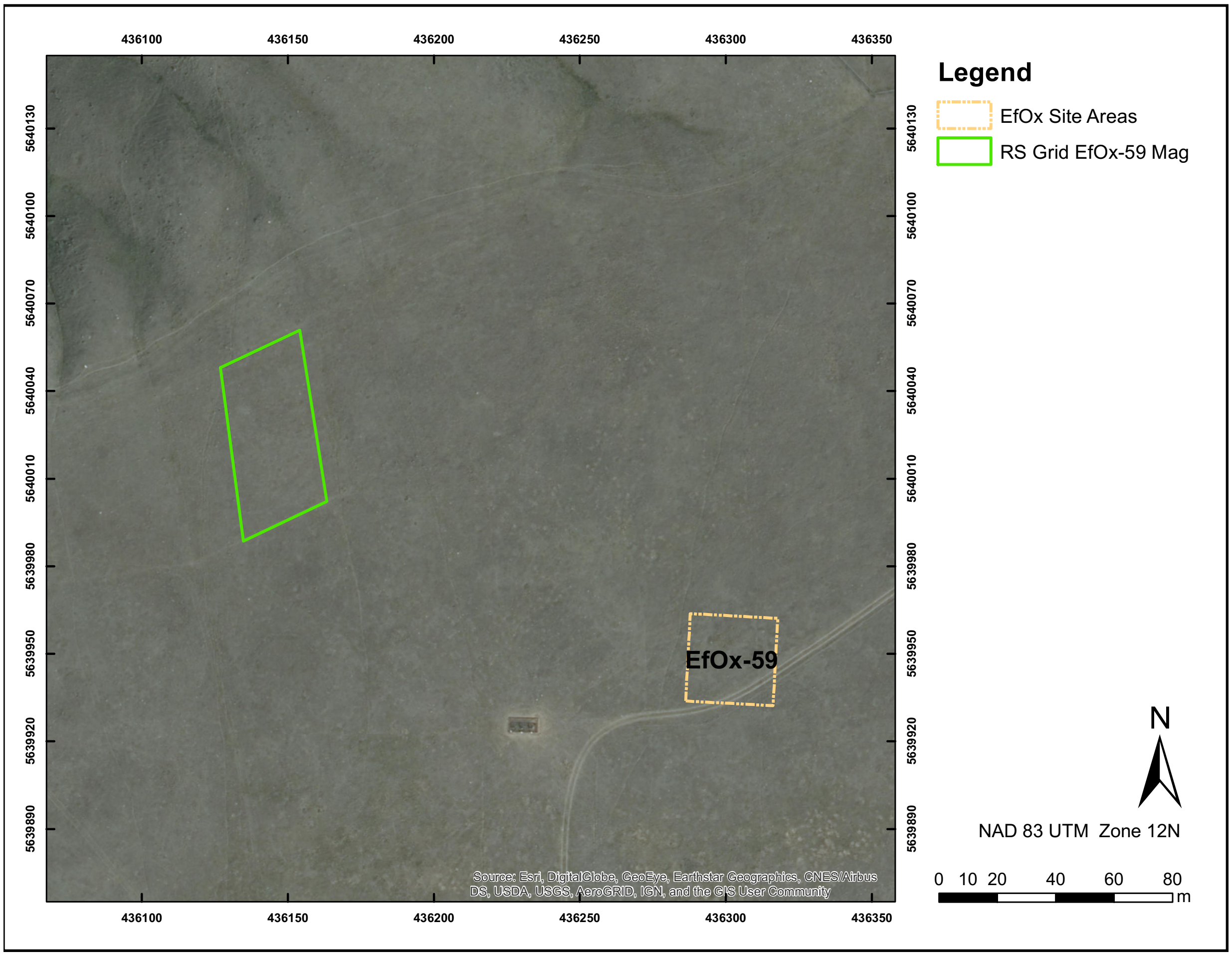

Figure 5.1: Placement of the EfOx-59 magnetometry grid in relation to the recorded site location.

grid, turned out to be an excellent image of what the underlying geology of the Red Deer River upper valley margin looks like.

Overall, the anomalies are spotty and of no particular pattern. Those areas of increased positive (pink) or negative (blue) values in *Figure 5.2* are likely isolated geological features, meaning they are likely individual rocks mixed up with the glacial gravels that include some magnetized materials. The donut-shaped anomalies in the data (see top circled area in *Figure 5.2* for example) are likely magnetic rocks with the poles lined up close to an up and down position with the negative pole above, and the positive pole below. There is also an anomaly in the southwest area of the grid that has

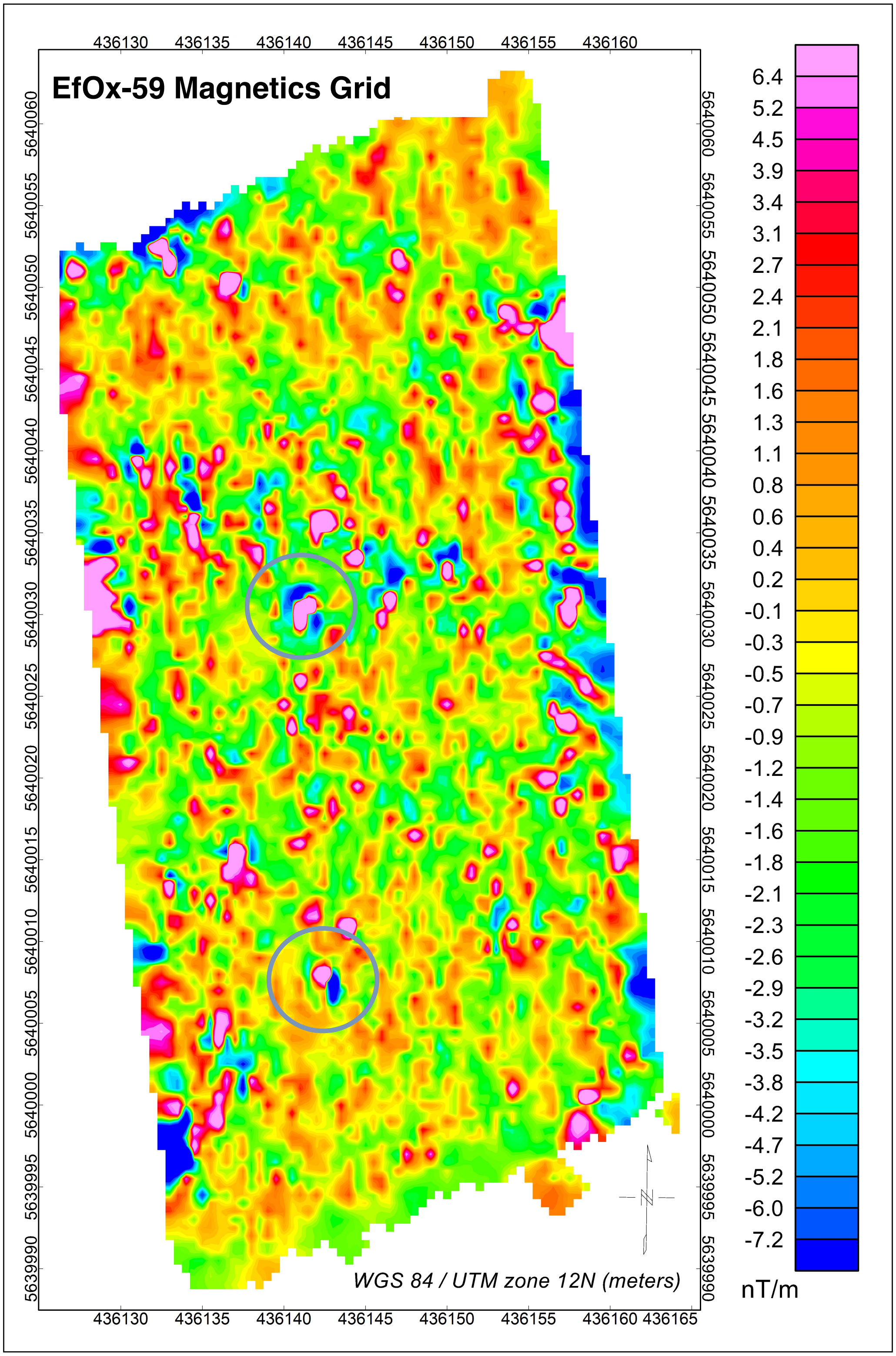

Figure 5.2: Magnetometry results in the grid northwest of EfOx-59. Note the donut shaped anomaly in the top circle, likely caused by something with its magnetic poles in a vertical alignment and the dipole pair in the bottom circle likely caused by naturally magnetic glacial erratics as they are out of alignment with the earth's magnetic field.

fairly clear dipoles (see bottom circled area in *Figure 5.2*), but based on excavation results at EfOx-80, is likely to be rocks because they do not line up with magnetic north. No excavations were done in this area because nothing clearly anthropological was showing up in the data compared to other grids.

EfOx-80 South

During the archaeological field school in 2012, EfOx-80 was recorded with eight or nine tipi rings, one of which was very clear on the prairie surface and was easily located again in 2017. That year, a 40 m by 40 m grid was set up with the located ring

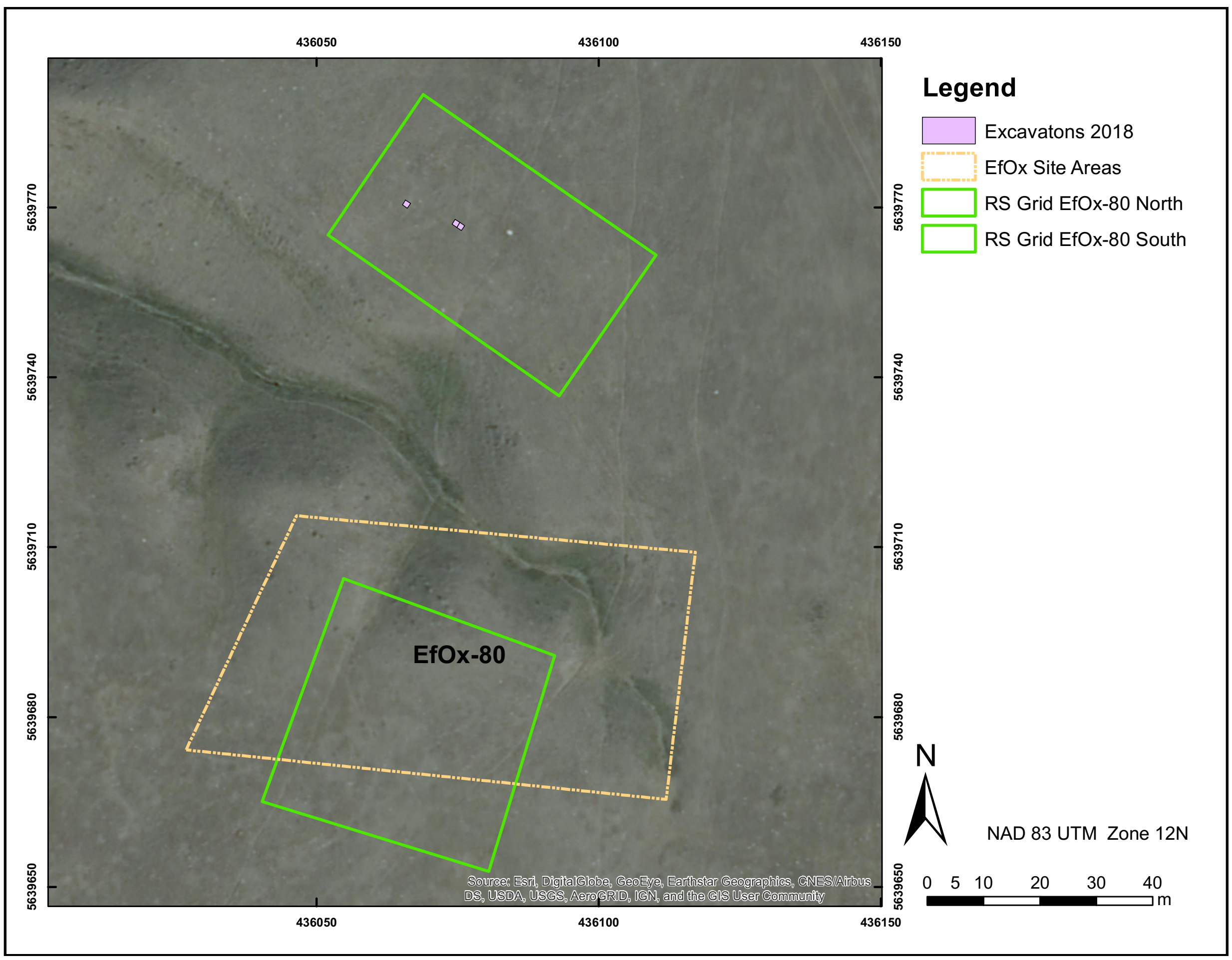

Figure 5.3: Placement of the EfOx-80 magnetometry grids in relation to the recorded site location.

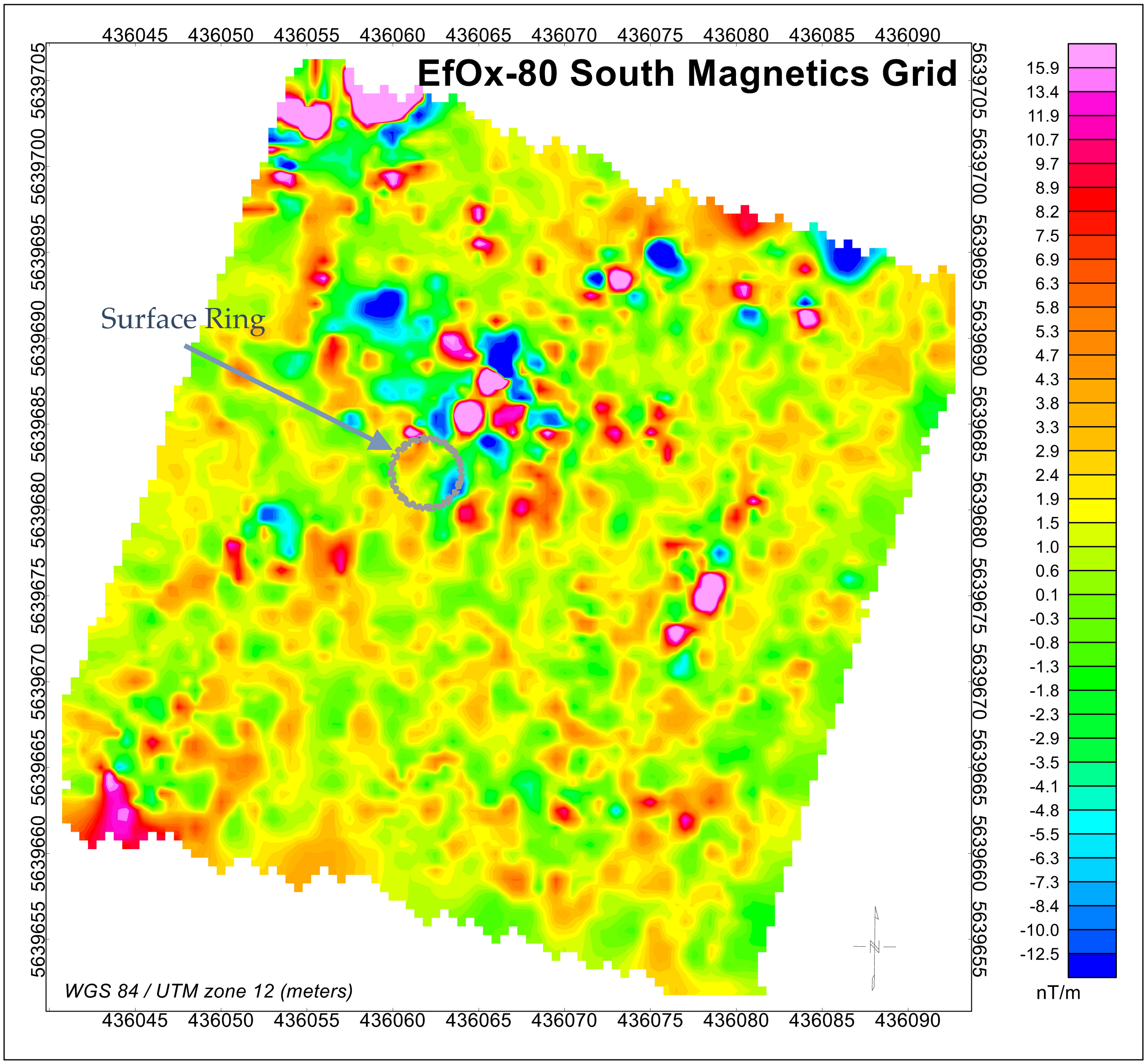

Figure 5.4: Magnetometry results in the south grid of EfOx-80. Note the cluster of magnetic anomalies directly north and northwest of the surface tipi ring.

near the centre (the south grid in *Figure 5.3*) to examine whether it would be visible in the magnetometry data, or if perhaps any of the other less visible rings were.

As can be seen in *Figure 5.4*, the clear surface ring did not really show up in the data except for individual anomalies on the northwest and southeast edges of the ring, likely because these are the only stones in the ring that have any magnetization. There are also a couple of dipole features along the coulee edge, but they aren't equal on their positive and negative ends as expected of something that would be flat on the ground when created, suggesting that they are likely from rocks.

The area north and a bit east of the surface ring however, does show quite a dense pattern of anomalies rather like those in the north grid of EfOx-80 caused by the surface exposure of glacial gravels. The difference here is that there is no corresponding exposure of gravels that might cause the anomalies, raising the question of what is causing them. It is possible that they are caused by very shallowly buried glacial gravels that are on the surface just north of this area but is also possible that the anomalies represent an activity area.

Human occupations, and especially palaeosols or other organic soils created by them, can lead to changes in the local magnetic field (Smekalova 2008). It would make sense for the area just outside a tipi to be densely used by its occupants for anything from cooking, (Kehoe 1960), food preparation in the form of drying meat or preparing pemmican, to a hearth to gather around, or even a play area for children. Shovel testing or even coring in this area might offer insight into what is happening here by determining whether there are glacial gravels or paleosols below the surface.

EfOx-80 North Grid

The magnetic gradiometry data on the north side of the coulee across from the recorded EfOx-80 site location (see *Figure 5.3*), showed the most promise for test excavations in 2018. The most obvious anomaly in the data is along the southwestern edge of the grid in an area where the prairie plateau dips slightly into the coulee along a cow path. The area forms a shallow bowl where numerous glacial gravels have been exposed on the surface as a result of eroding out of the edge of the coulee.

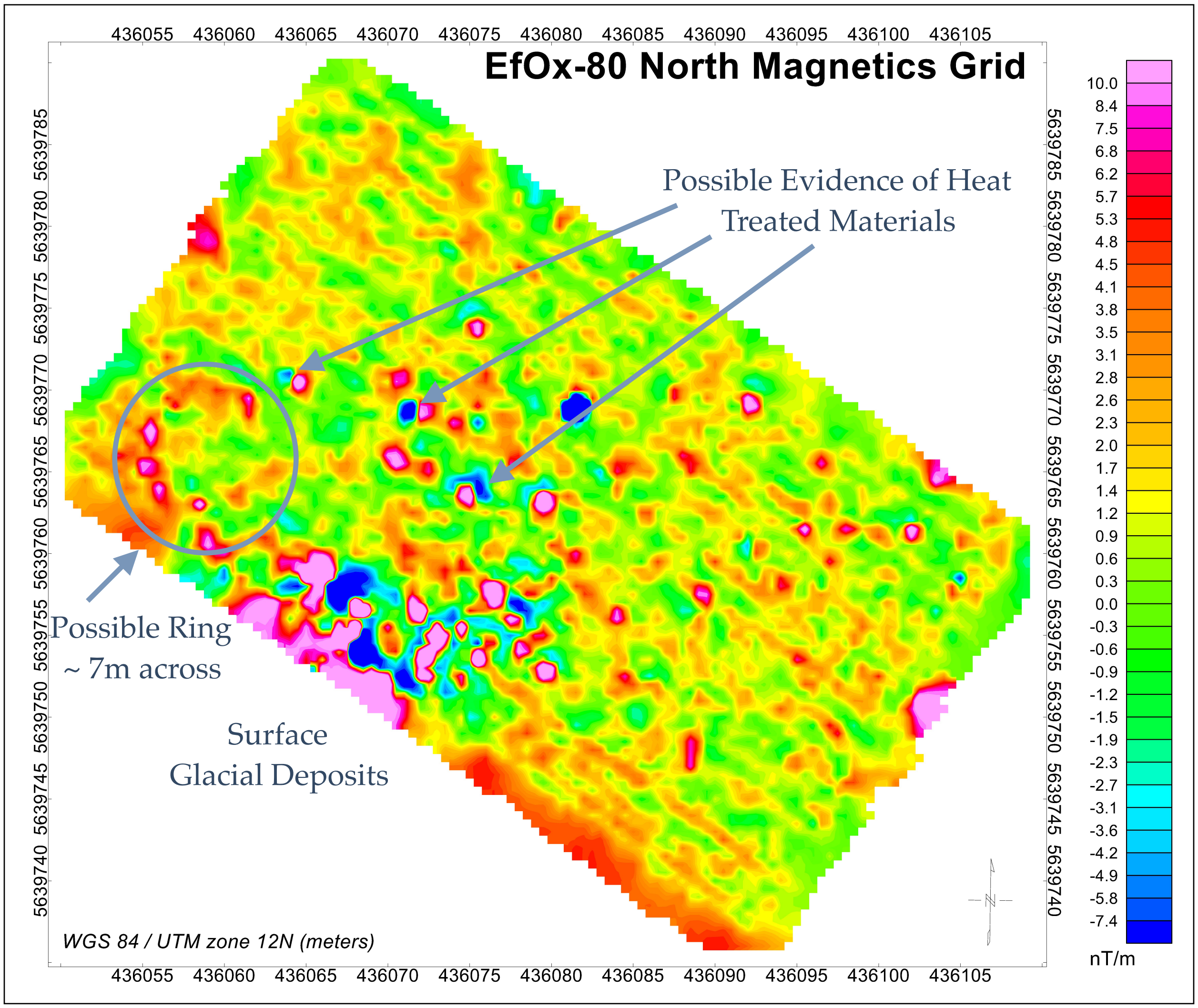

Figure 5.5: Results of magnetic gradiometry in the northern grid at EfOx-80. Note the dipoles near the centre of grid that may be evidence of heated materials, and the ring of anomalies in the western corner. Magnetometry results in the north grid of EfOx-80. Note the cluster of magnetic anomalies directly north and northwest of the surface tipi ring.

Slightly less obvious, in the far western corner of the grid (see circled area in *Figure 5.5*), there is a roughly tipi sized (~6.6 m to 7.5 m) circular anomaly. In the summer of 2018, a suspected hearth was mapped on the western edge of where this ring shows up and flake artifacts were collected from this area as well. Interestingly, the hearth rocks are visible on the surface, but any possible ring rocks are not. The orange anomalies around the western edge may be the result of the hearth but unfortunately, this area could not be excavated with the limited time and resources that were available.

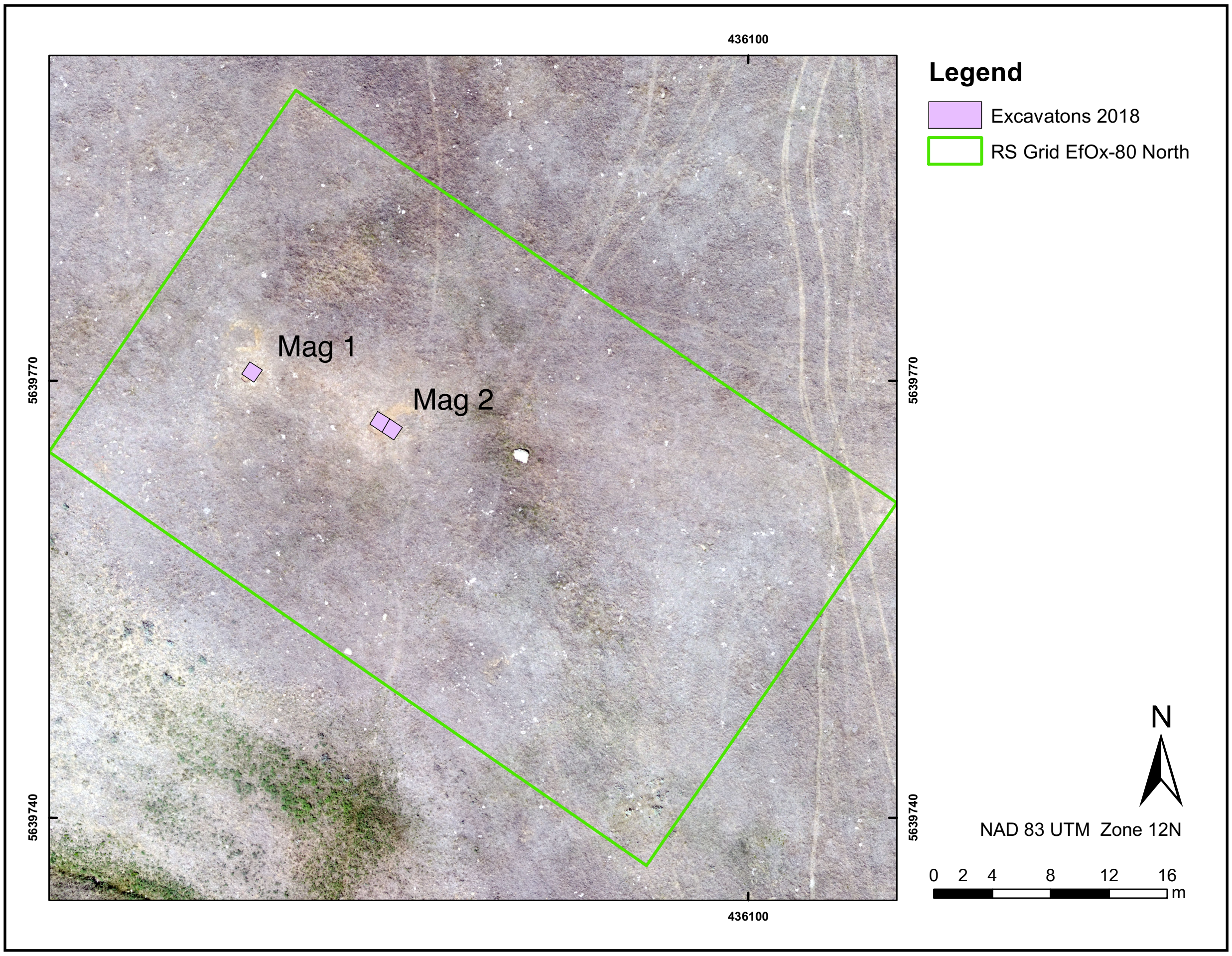

Figure 5.6: Locations of Mag 1 and Mag 2 excavation units in the EfOx-80 north grid.

Instead, three anomalies were identified as possible hearths and the northwestern-most two of the three were excavated (see *Figure 5.6* for excavation locations). These excavations showed that the anomalies were likely caused by rocks found just below the surface.

The first and most northwestern area of excavation (Mag 1) was 1.0 m by 0.5 m in size and aligned with the grid used to do the magnetometer survey. Two rocks, shown in *Figure 5.7*, roughly 40-50 cm in size each were excavated from near the surface that were the likely source of the magnetic anomaly. Both rocks have been broken, but the cause looks as though it could have been fire or simple weathering in the form of

Figure 5.7: Rocks found in excavation area Mag 1 of the EfOx-80 north grid that were a likely source of magnetic anomaly.

Figure 5.8: Rock found in excavation area Mag 2 of the EfOx-80 north grid that is likely source of magnetic anomaly.

exposure to the freeze/thaw cycle. More testing is required to determine if they were heated or have any magnetic properties, but it could not be arranged due to the closure of the university labs and buildings by COVID-19.

In the second area of excavation (Mag 2), shown in *Figure 5.8,* there was one rock just 1 cm to 2 cm below the surface that was likely the cause of the anomaly. The rock displays similar breakage to those found in the first excavation unit, and all three of them could be tested for their magnetic properties to confirm them as the sources of the anomalies when the labs reopen.

Magnetometry Results along Matzhiwin Creek

EfOx-77 Area A

The data in this area was collected in four grids over the summers of 2018 and 2019, after the archaeological field school excavations in 2017 (see *Figure 5.9*). The original Area A grid was set up and collected in 2018 and was the largest at EfOx-77, measuring 24 meters by 32 meters to cover a rise overlooking the lower terrace of

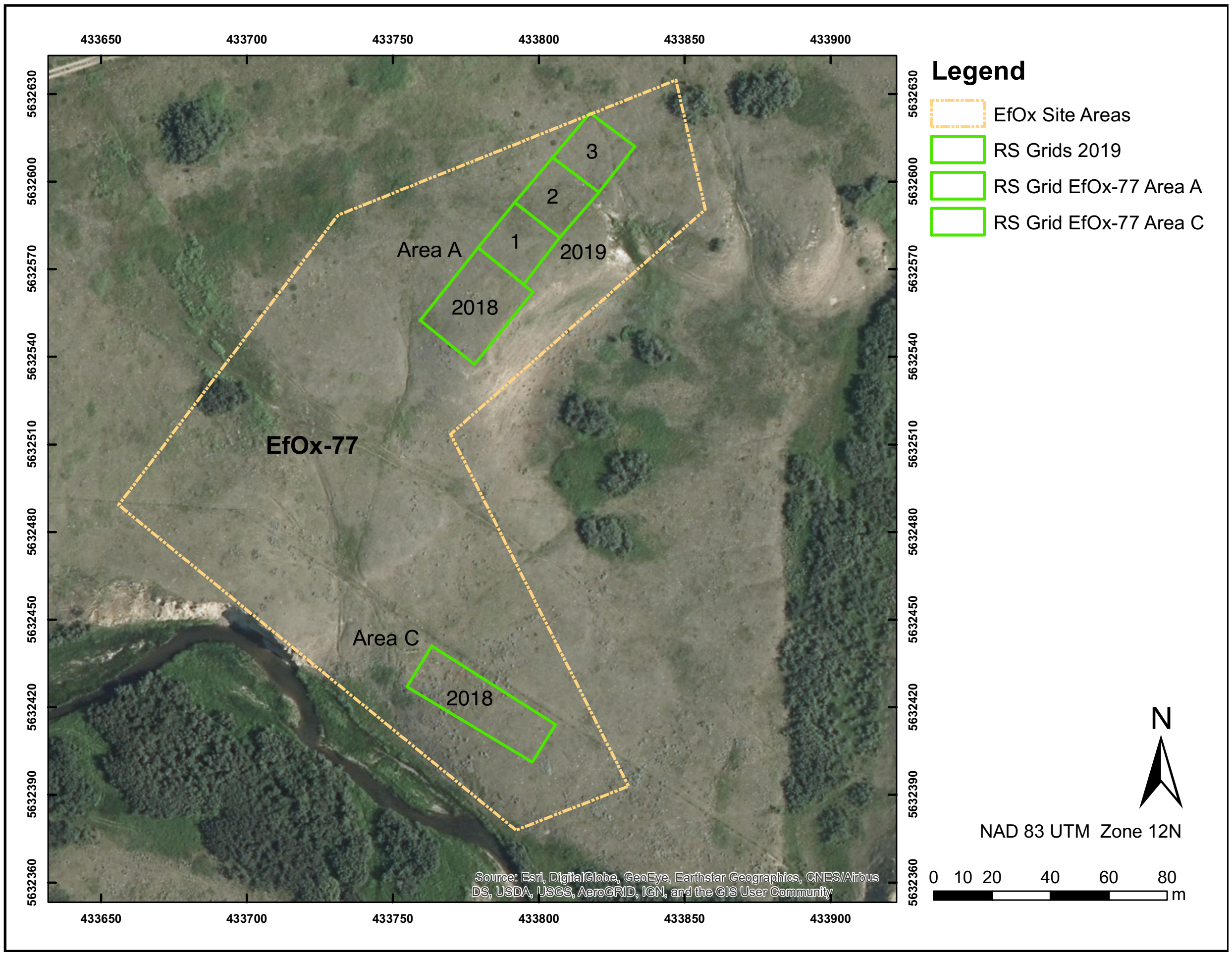

Figure 5.9: Locations of the geophysics collection grids at EfOx-77.

Matzhiwin Creek about 5 meters below. Three more 20 meter by 20 meter grids were added off the northwest edge of the 2018 grid to serve the dual purpose of giving the 2019 field school students experience with GPR and magnetometry, and to extend the surveyed area to cover where a hearth feature had been excavated in 2017.

The 2017 excavations showed that this area was mostly sand, but there were bone fragments and a hearth feature excavated in the northwestern units (*Figure 5.11*). The uniform sand is reflected in the gradiometer data in *Figure 5.10* as there is very little in the way of anomalies in it. Natural exceptions are the sage brush in southernmost tip

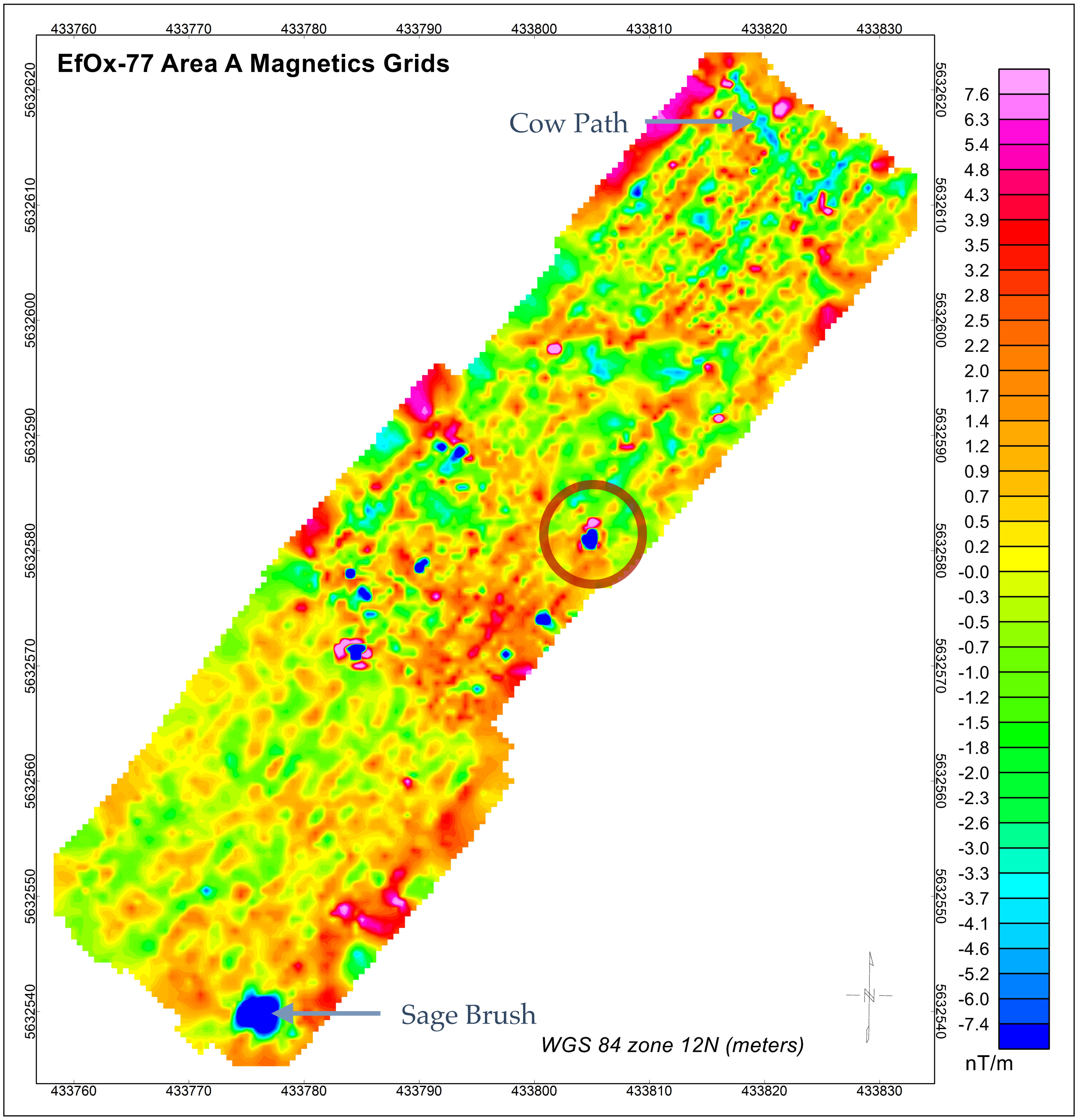

Figure 5.10: Results of the magnetometry data collection at EfOx-77 Area A in 2017 and 2019. Note the north-south circled dipole anomaly that warrants further analysis.

of the original grid that shows up really nicely, as does a cow path going down the slope towards the creek in the northernmost grid.

The low variation in the gradiometer values bodes well for locating buried hearth features in future excavations, as they should show up as roughly north/south aligned

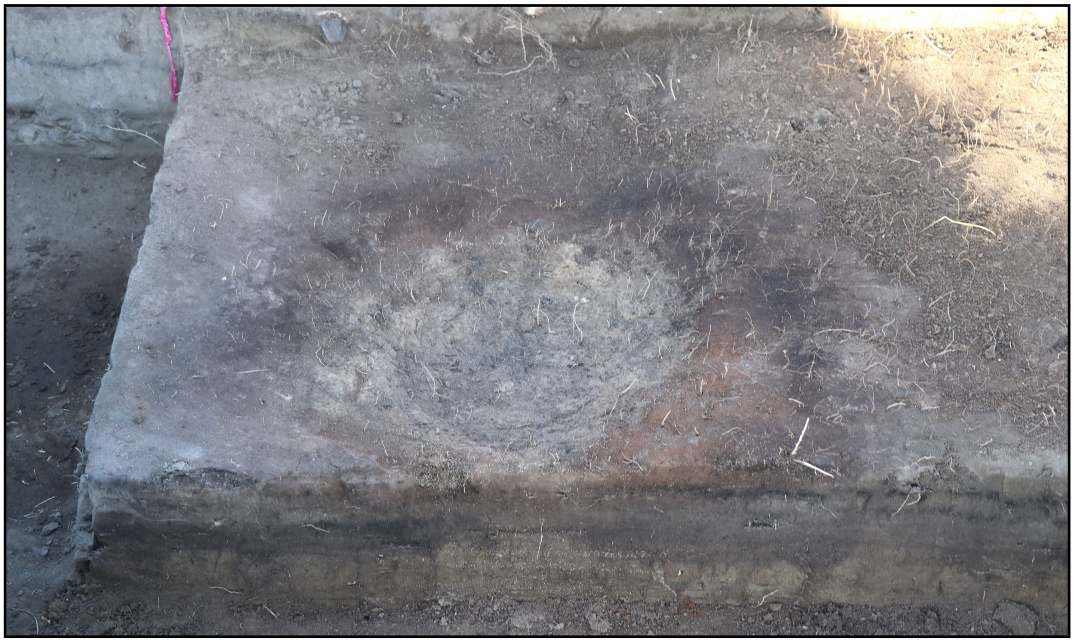

Figure 5.11: Ash, charcoal and oxidation from a hearth feature excavated in 2017 at EfOx-77. The geophysics grids in Area A were expanded in 2019 to include this previously excavated area. AMS dates show that this feature is from the same time period as similar features from EfOx-70 across Matzhiwin Creek.

magnetic dipoles of 5-10 nT/m more magnetic than the surrounding environment. One such anomaly does occur on the data collected in 2019 (see circled area in *Figure 5.10*) and could be investigated further through excavation.

Future work should expand even further on these grids, especially to the north and as far east as the power transmission lines next to the highway will allow to look for any more dipole anomalies. Archaeological sites discovered when the lines were being constructed show that there were activities happening further east at EfOx-73 and EfOx-74. A thorough magnetic survey between the power transmission lines and Area A of EfOx-77 could offer some ideas about where to look for more site features and help connect the archaeological landscape together.

EfOx-77 Area C

The magnetic gradiometer data in Area C of EfOx-77 was collected in 2018 after the field school excavations in 2017. The grid examined was laid out on a long and narrow strip of land between a barbed-wire fence on the top long edge, and a drop down to the creek bank on the other. Excavations a few meters northwest of the end of the grid found layered clay and silt with bone and lithic flakes down to about 1.2 m.

Results in *Figure 5.12* show that the gradiometer values are all very low—only +/- 3 nT/m, within the error range of the instrument—suggesting a very uniform subsurface makeup. A small cairn (a pile of rocks formed by humans) near the top of grid, shows up

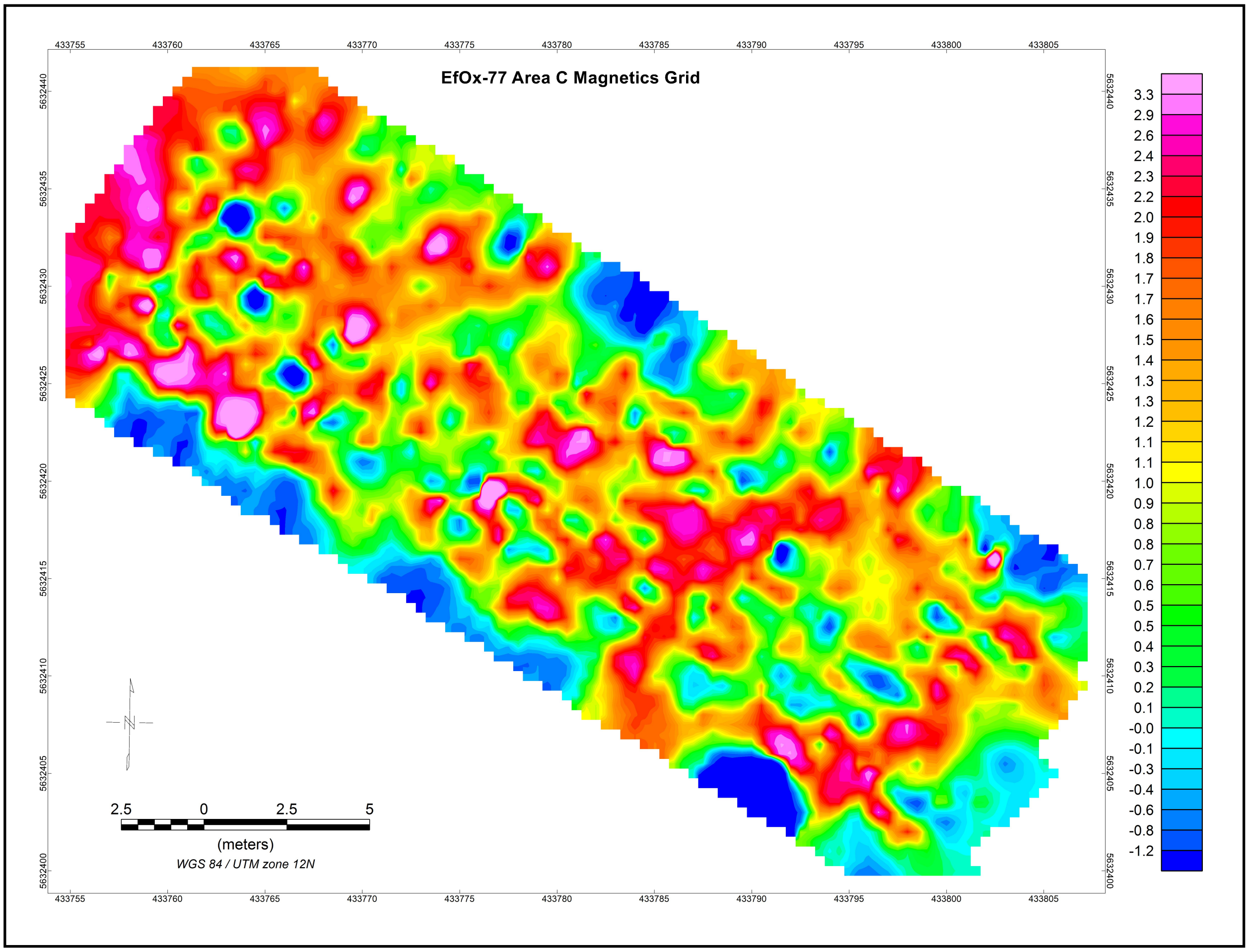

Figure 5.12: Magnetometry results from Area C of the EfOx-77 site along the bank of Matzhiwin Creek. Note the low gradeomtery values within the error range of the instrument.

as a negative anomaly. This is likely the result of awkward walking over and around the pile when the data was being collected.

The uniform results make sense given the fairly deep sand and silt layers that have been alternately eroded and deposited by the creek over time. The trouble is that it can be difficult to determine if the artifacts being found are in situ, or if they have been washed to their present location by the movement of the creek. It is also possible that the majority of the cultural sediment layers have been washed away, as discussed in the last chapter. Future surveys should examine further back from the creek bank between Area A and Area C to determine if there are any anomalies there that have not been impacted by creek floods. Based on the low gradiometer values here and in Area A, any cultural anomalies should be easily visible in the data.

Discussion

The challenge of magnetometry data collection with the sites along Matzhiwin Creek is that most of the known sites are directly under the power transmission lines that have a noticeable effect on the gradiometer results. Magnetic gradiometry surveys conducted at EfOx-77 show that the sandy matrix is a good background for finding cultural features but is likely to be more successful further east of Area A, towards the power transmission lines. The bowl-shaped terrace feature between Areas A and C is another potential target that is less likely to be impacted by relatively recent flooding of the creek.

Two lines walked with the gradiometer show that the power lines have a significant and observable effect on the data collected. The test data was collected by

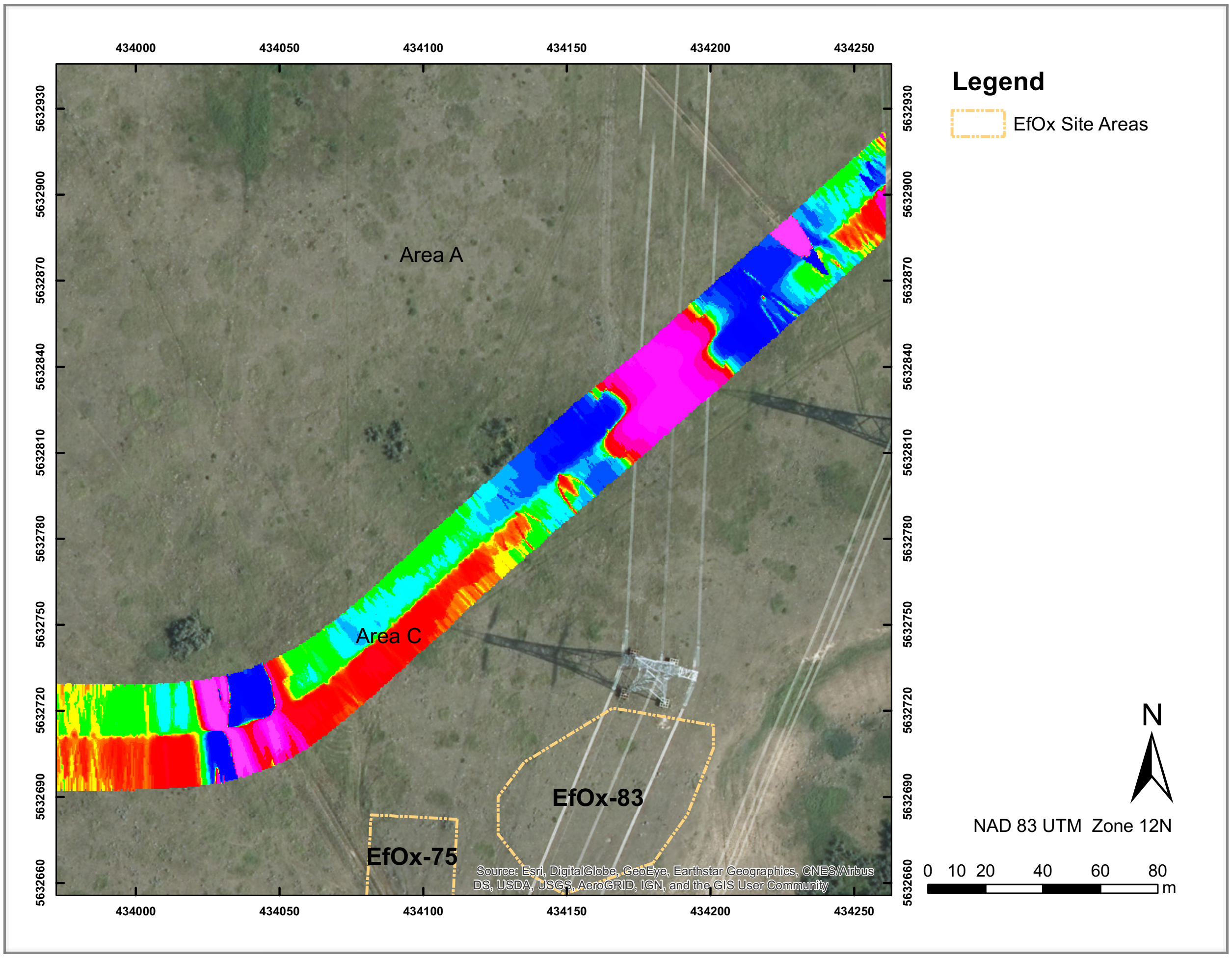

Figure 5.13: Magnetometry results along an access road going under the power transmission lines in the area of the Matzhiwin Creek sites.

walking along the access road that runs north of EfOx-77 from the site, under the power transmission line in the south tire track and back again about 1 meter over in the north tire track. The results from the two lines were significantly blurred out from the road during processing, making the results more visible for the extent of the lines rather than two narrow lines. The results in *Figure 5.13* show a large area of high returns in pink around the power lines representing a positive anomaly, with a corresponding negative dipole represented by the blue beyond that. There are similar results from an area where the road bends that has a definite dipole on each line caused by a marked pipeline that runs under the road. These spikes in the data under the power lines represent an increase of five to ten fold in the gradiometer data and from four to five fold over the buried pipeline. The background magnetic gradient shown in the areas of green, yellow and red indicate a gradient of +/- 10 nT, where the power lines record a gradient of +/- 125 nT.

The Red Deer River area sites present a different type of challenge in that there is a pastiche of glacial deposits only about 30 cm below the surface. These deposits are poorly sorted and contain a wide variety of different types of rocks, including iron stone, that have varying levels of inherent magnetism. In some areas, the till may be too close to the surface and contain too wide a variety of materials all mixed up together and dumped by glaciers, to allow for accurate magnetic detection of anything anthropological. If the till contains too many randomly placed rocks with magnetic properties it will be difficult to find anthropogenic remains, especially given that we know there is ironstone in the area.

A similar problem was encountered by Hamilton et al. (2007) at the Snyder II site in Manitoba where undulations in the underlying till periodically comes close enough to the surface to be detected. In this case, the periodic nature of the undulations made the naturally magnetic rocks masquerade as archeological features. In the case of the Mattheis Ranch sites along the Red Deer River valley margin, possible features are more likely to be masked by the natural deposits the archaeological features are resting on.

Despite this, there are some locations, especially in the area of EfOx-80, that warrant further investigation. The tipi ring sized circular anomaly in the north grid could, with time and workers, be excavated to determine what created it. The area northeast of the surface ring in the south grid could also be tested to see if the anomalies there are caused by a possible organic layer, shallow glacial till deposits, or some other source. The anomalies in both grids contain magnetic gradients of +/- 5 nT more than the surrounding gradients and +/- 10 nT more than then the values recorded at EfOx-59, suggesting that some of the archaeology could stand out against the glacial till but increased testing would have to confirm this.

Overall, the magnetometry data has offered some hints that it is useful for identifying certain archaeological targets on Alberta Plains sites, though care must be taken to understand the surficial geology being tested when considering targets for excavation. The results at EfOx-80 offer the best indication of success but cannot be confirmed without further testing.

The expanded area of magnetometer work done at EfOx-77 in 2019 is intriguing, and the fact that these 20 meter by 20 meters grids were collected in about an hour each once the grid was established bodes well for being able to examine larger areas fairly quickly. If time had been permitting, it would have been nice to continue doing a larger area around EfOx-77 to mark out exactly where the pipeline is and to see if any other archaeological features can be located.

Overall, the magnetometry results test carried out at the Mattheis Ranch sites showed that the sandy conditions along Matzhiwin Creek are definitely preferable for the visualization of magnetic anomalies because the difference between any anthropological signal and the background sand is more likely to be visible. Results at EfOx-80 along the Red Deer River upper valley margin show that it is still possible to get meaningful results in less ideal conditions like glacial till if features have been used enough to have a different enough signal.

For those areas below the powerlines, GPR became the most important method of understanding the subsurface makeup of the Matzhiwin Creek sites, as will be described further in the next chapter.

Chapter 6 - Ground Penetrating Radar

> "[GPR] is the best near-surface geophysical method that characterizes the three-dimensional arrangement of subsurface geological units and associated archaeological features." (Conyers 2017)

How GPR Works

Ground Penetrating Radar (GPR) is a method of ground-based remote sensing that uses RADAR (RAdio Detection And Ranging) technology. A pulse of microwave energy, generally in the 80-1000 mHz range (Heimmer and Vore 1995), is sent out from a transmitter and then the time it takes for the signal to return from reflecting off various layers of soil and inclusions is measured. Different materials will reflect the microwave energy differently depending on its density and material makeup.

Ground-based Radar sends a cone shaped electromagnetic signal that makes for bell-curve shaped elements in the profile view of the results. It creates an increasing signal as the cone encounters a feature ahead, getting the strongest signal directly overhead and a diminishing signal as it moves away. So, as the instrument is dragged up to a feature, such as a cement or rock footing of an otherwise demolished building, the reading will begin to show as the GPR collects readings off the side as it comes up to it, get the highest and nearest reflection off the top of the footing where it is closest to the surface and then deeper readings off the sides of the walls as the GPR antenna moves away (Conyers 2012).

The success of a GPR survey depends on "soil and sediment mineralogy, clay content, ground moisture, depth of burial, surface topography, and vegetation" (Conyers 2013: 24), all of which impact the likelihood of receiving a return signal. Electrically conductive soils and sediments, including some types of clay such as Bentonite, which is found in the Red Deer River valley up and downstream of the Mattheis Ranch[3] (Lerbekmo 2002, Thomas et al 1990), create an environment where the GPR energy is transmitted away. The same is true for salty or brackish water. Fresh water and ice, on the other hand, are excellent mediums for radar energy transmission and even high frequency radar energy can travel to great depths and back in these environments (Conyers 2017, Urban et al. 2016).

> Since archaeological features often affect water saturation in the subsurface or may be of significantly different composition of the host material, they may be excellent radar targets, if subsurface conditions permit observation of contrasts. Overall, the general approach is to observe anomalies from the normal background data. To aid this process, ground truthing or excavation of observed features is highly recommended as the survey progresses. (Heimmer and Vore 1995; p 46)

As with the rest of archaeology, context is key when interpreting GPR results, and it requires very special circumstances to be able to identify archaeological remains without having some idea of what they are. In contexts where the remains being sought are those of stone building foundations, structures such as French basilicas or Roman villas may be recognized by their distinctive footprints. In most North American contexts however, results are more murky and testing in the form of excavation or soil probes is required for definitive identification.

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[3] Bentonite in the Red Deer River valley is up to 200 m below the prairie surface on the Mattheis Ranch, so well below the depth of the work presented ehre. Outcrops do occur near the bottom of the Red Deer River Valley in Dorothy and in Dinosaur Provincial Park and should be kept in mind when evaluating the suitability of near-surface GPR studies in the river valley bottom. (Lerbekmo 2002; Thomas et al 1990).

GPR data is often used to find features such as building foundations, roads, and filled in ditches, privy holes and other disturbances to site stratigraphy (Conyers 2012). North American archaeologists have been increasingly using GPR in the context of post-european contact sites to relocate burials (eg: Bigman 2014, Doolittle & Bellantoni 2010, McKeand 2012, 2015, 2016, 2017, 2018, 2019, McKeand & Gadd 2020, Wadsworth et al. 2020); forts (eg: Finnigan et al. 2012); and Métis settlements (Wadsworth et al. 2021).

In a pre-european contact context, GPR has proven useful in learning about the construction of Middle Woodland mounds (King et al. 2017); locating the boundaries and volume of discarded chert at a quarry on Baffin Island (Landry 2018); and in identifying the volume and construction of shell middens (Conyers 2012, Miller et al. 2018). Adobe walls and burned or heavily compacted dwelling floors have also been identified (Conyers 2012).

Although there are no walls or foundations expected in this project, the hypothesis here is that the rocks left behind in a tipi ring will be sufficiently different from the surrounding matrix that the suggestion of a circle should be visible in a plan view of the resulting imagery. This does depend heavily on the makeup of the soils of the site, as too many rocks and glacial deposits may cause too much noise for tipi ring patterns to be separated out.

The presence of thick bone beds and bone features in EfOx-70 and EfOx-71 also offer the opportunity to test whether the bone is sufficiently different from the surrounding sand to be visible to the radar waves.

GPR Methods

All the GPR data presented here was collected using a Geophysical Survey Systems, Inc. (GSSI) TerraSIRch SIR® System-3000 (SIR 3000) connected to a 400 MHz antenna provided by the Baikal Archaeological Project at the University of Alberta. Some grids were collected using a cart setup in which the antenna is pushed over the ground attached to the bottom of a 3-wheeled cart, while others were collected dragging the antenna over the ground with a survey wheel towed behind. Since no global positioning system (GPS) is attached to the unit, the grid corners were mapped using a total station and RTK unit.

Lines within the grids were walked every 50 cm along tape measures to ensure they were as straight and regularly spaced as possible over the slightly uneven ground. The short grass prairie vegetation offered almost no impediment to the creation of square grids and straight lines, with the exception of occasional sage brush and larger rocks.

The GPR line profiles were reviewed in RADAN 7 software and in Lucius and Conyers GprViewer application. The gains were adjusted in the profiles from their collection values to emphasize changes in the speed of the radar wave, but otherwise they remain unprocessed. The plan view slice grids were generated using Conyers et al. GPR_Process software that reorganizes the results of the vertical profiles into a three dimensional block and slices them into planes on the horizontal. It then generates files that can be gridded for display in Golden Software's Surfer 10 software.

GPR Results along the Red Deer River Valley

EfOx-59

Both grids labeled as EfOx-59 were actually located northwest of the recorded location of EfOx-59 as shown in *Figure 6.1* because the site could not be relocated through field inspection or airborne imagery (see pages 72-73 in magnetometry chapter). The data for both grids was collected using the GPR cart setup and zig-zag pattern in which data was collected both in the northern direction and in the return southern direction.

EfOx-59 East

GPR data collection on the east grid of EfOx-59 took place over two days starting May 22 and finishing May 23, 2018. This difference can be seen as a line in the GPR

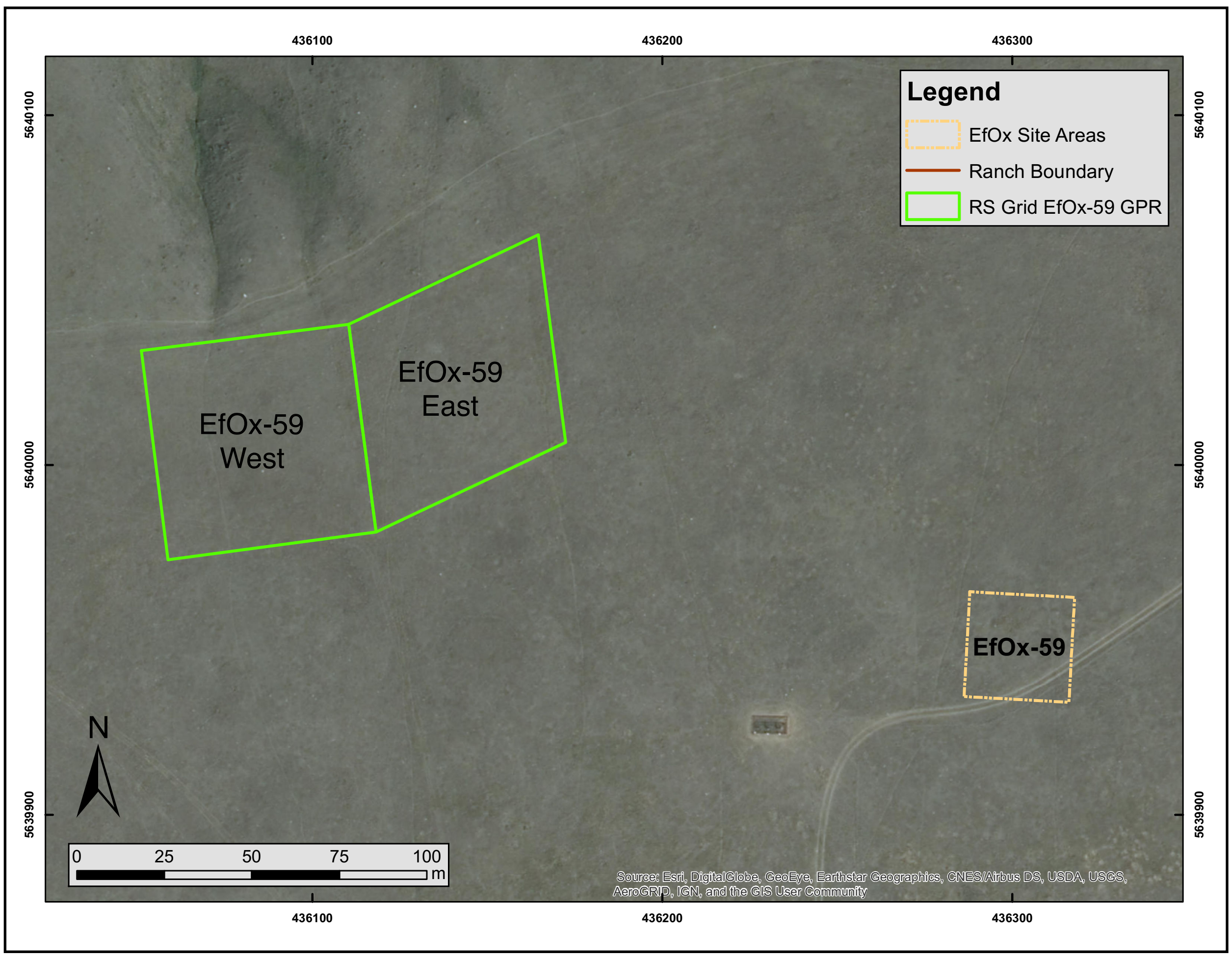


Figure 6.1: Locations of northern GPR grids and sites.

data when the data are sliced in plan view as in *Figure 6.2*, but the wetter conditions on the first day diminish in effect the deeper the signal goes. With little difference between the moisture conditions at the lower levels of interest, no correction was done.

The collection grid is 60 m on all sides but shaped like a parallelogram rather than a square due to a calculation error in the field. The magnetometry data collected at

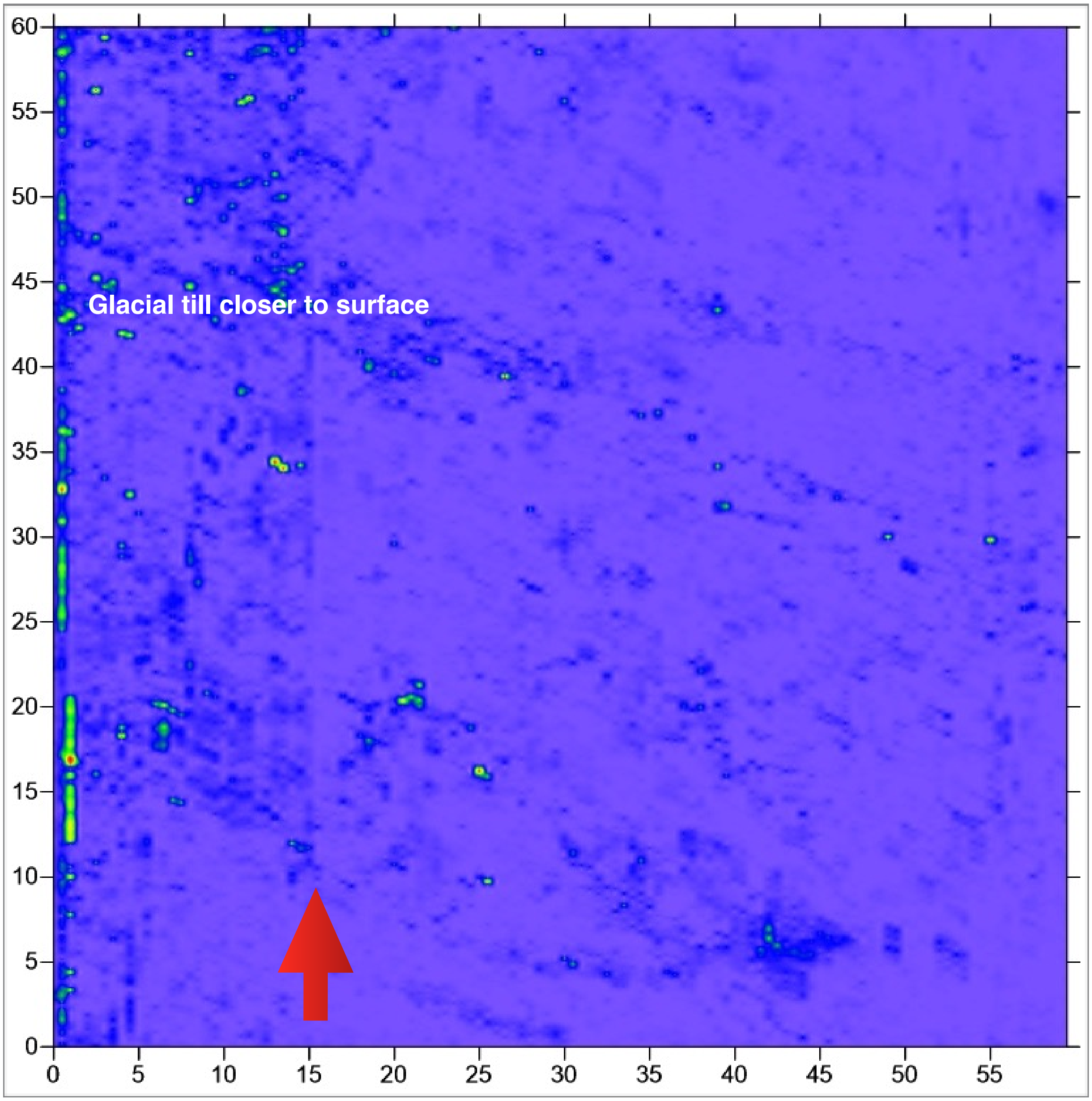


Figure 6.2: Slice 3 (4-6 ns) of the EfOx-59 east grid. The arrow highlights the differing results from day 1 where there was more water in surface levels of the ground and the drier conditions on day 2.

this location shares a north-south central line with the parallelogram, but is only 30 m wide.

EfOx-59 West

The western grid is directly west of the eastern gird, sharing its eastern side with the eastern one. This grid was also 60 m wide and properly square shaped. The

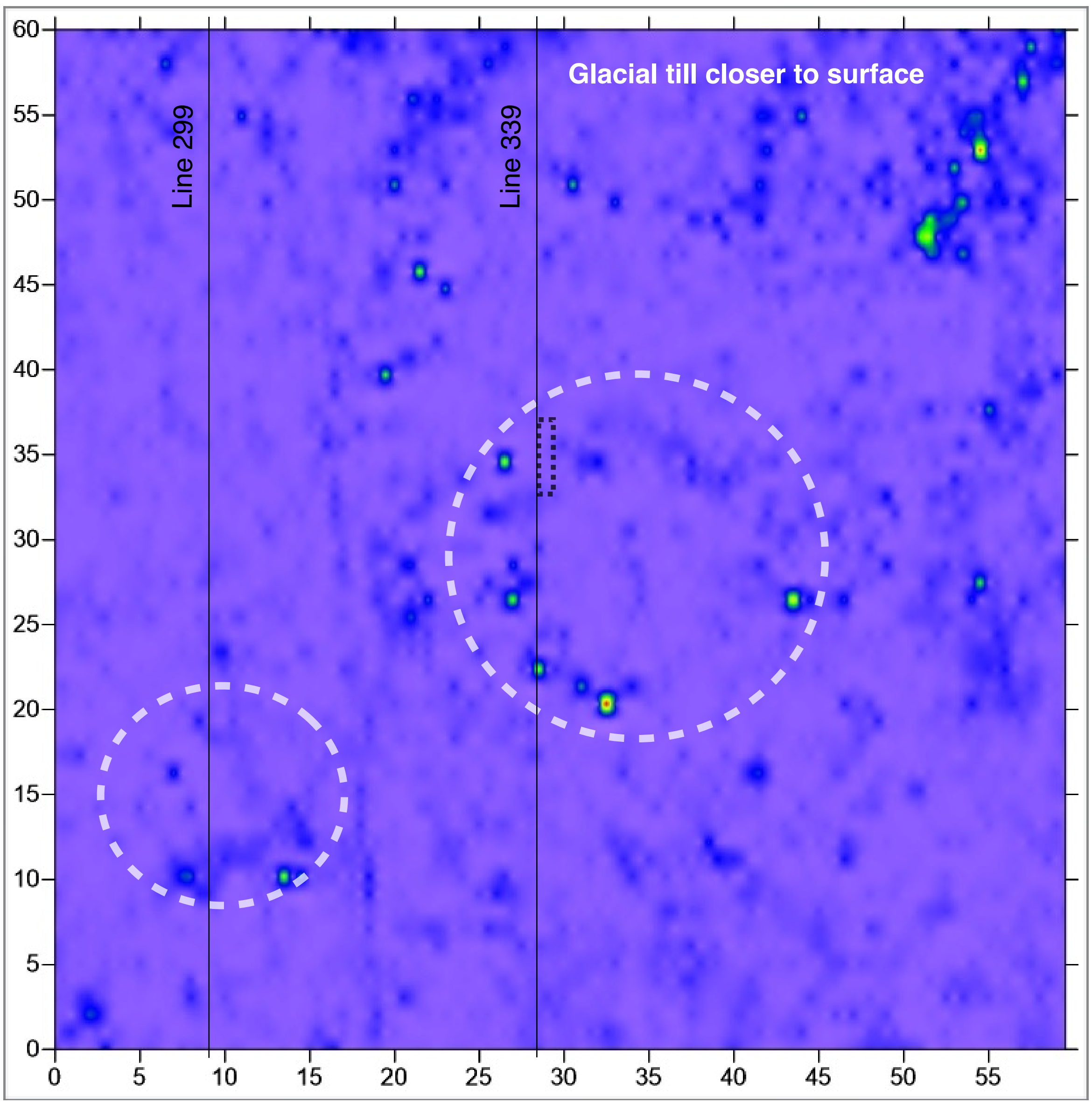


Figure 6.3: Slice 3 (4-6 ns, ~ 20-30 cm below surface) of EfOx-59 west grid showing the circular feature with the location of the excavation, and the smaller circular feature that looks like a pit in the profiles (eg. profile 299).

northern edge was aligned along the upper valley margin of the Red Deer River in this area, which meant it had an orientation only a few degrees west of north-south. The data for this grid was collected all in one day on May 23, 2018.

Results of the EfOx-59 Grids

The profiles across both the east and west grids are a jumble of point sources, likely reflective of the glacial till on and near the surface on this northern edge of the Duchess sand dunes. The denser point sources along the north edge of the grids are likely due to glacial till closer to the surface as the ground starts to slope down towards the river here and there is less sand cover closer to the edge.

There is a pit-looking feature of higher amplitude returns in the profiles (*Figure 6.4* shows an example from line 299) near the SW corner of the west grid that is about 7 m long and maybe 2.5 m wide and no deeper than 50 cm. The feature can be seen as a circle in the planar slices as well, especially in the 8-10 ns (~ 42-55 cm below surface) range in the circled area of *Figure 6.3*, but the edges can also be seen a little above and below in the slice profiles.

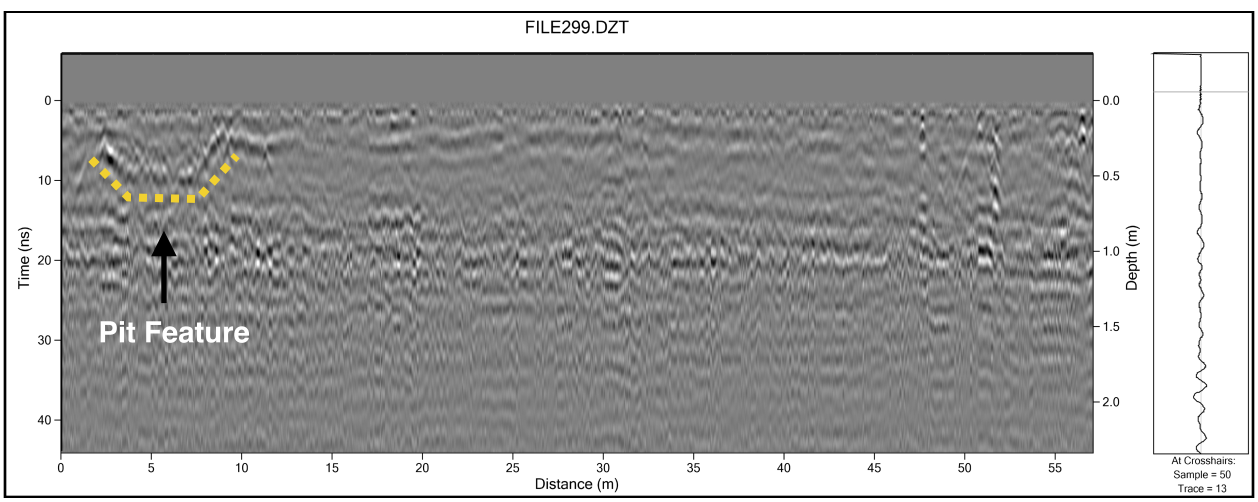


Figure 6.4: Line 299 shows the pit feature in the southwest corner of the western grid at EfOx-59.

There is a circular pattern of higher amplitude signals circled in *Figure 6.3*, including some discrete point sources near the centre of the west grid at a depth of 4-6 ns (~20-35 cm below the surface) that was chosen for a test excavation.

Excavations yielded no cultural materials, and upon post-fieldwork reflection, it was determined that the ring feature in the GPR data is nearly twice the size of even the larger end of average tipi rings (Kehoe 1958) at 15-17 m wide. It might have been archaeologically more interesting to determine the source of the pit feature mentioned above as the size and denser material indicated by the slower radar signal suggest a boiling or storage pit, or possibly a rodent burrow. Further investigation would be required to make a final determination.

The excavations did give an interesting look at the stratigraphy of the glacial till at the upper valley margin of the Red Deer River Valley. There is very little to see in the GPR profile that runs over where the excavations occurred (see *Figure 6.5*), though if they had continued a few meters to the south, some larger rocks would have been

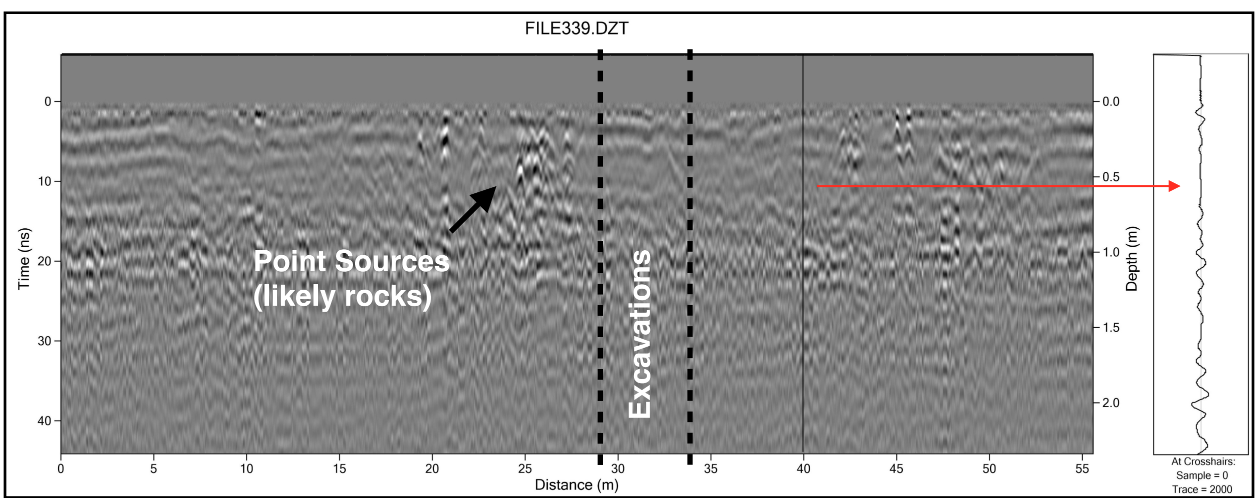


Figure 6.5: File 339 showing where the excavations units would be dug in EfOx-59 West and their relative depths and the cluster of point sources to the south. Note the layer changes in the trace (narrow solid line) and its amplitude graph to the right.

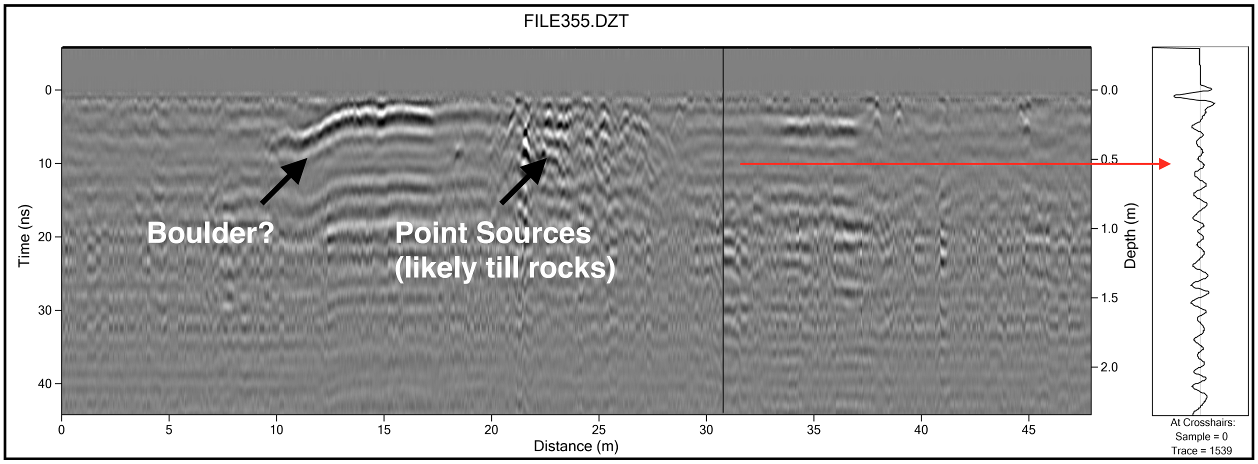


Figure 6.6: Profile 355 that from EfOx-59 West shows the constant velocity area with comparatively unchanging signal velocity in the amplitude graph.

encountered, but there is still some doubt whether they would have been part of a tipi ring.

One interesting thing that shows up in the GPR profiles—and in the stratigraphy—is that there seems to be a layer of relatively unchanging signal velocity between about 30 and 80 cm down depending on the profile (see the profile of line 355 in *Figure 6.6* for example). In the excavation profiles, this area turns out to be a hard-packed grey sandy/silty soil which contained the majority of the larger rock and root inclusions. Above it is a medium brown hard sandy soil and below it is a compact hard grey silt. Although there is no high amplitude layer change between the layers—likely due to the mixing visible in the soil profiles—the trend is visible in the profiles and the traces.

EfOx-80

The GPR data collection at EfOx-80 used the same 50 x 30 m north grid as the magnetic gradiometer data and was collected on the same day, but the data are a bit tricky to process into planar slices because of difficulties with the GPR cart. The posts that allowed the bucket to move with the ground surface bent so the antenna kept de-

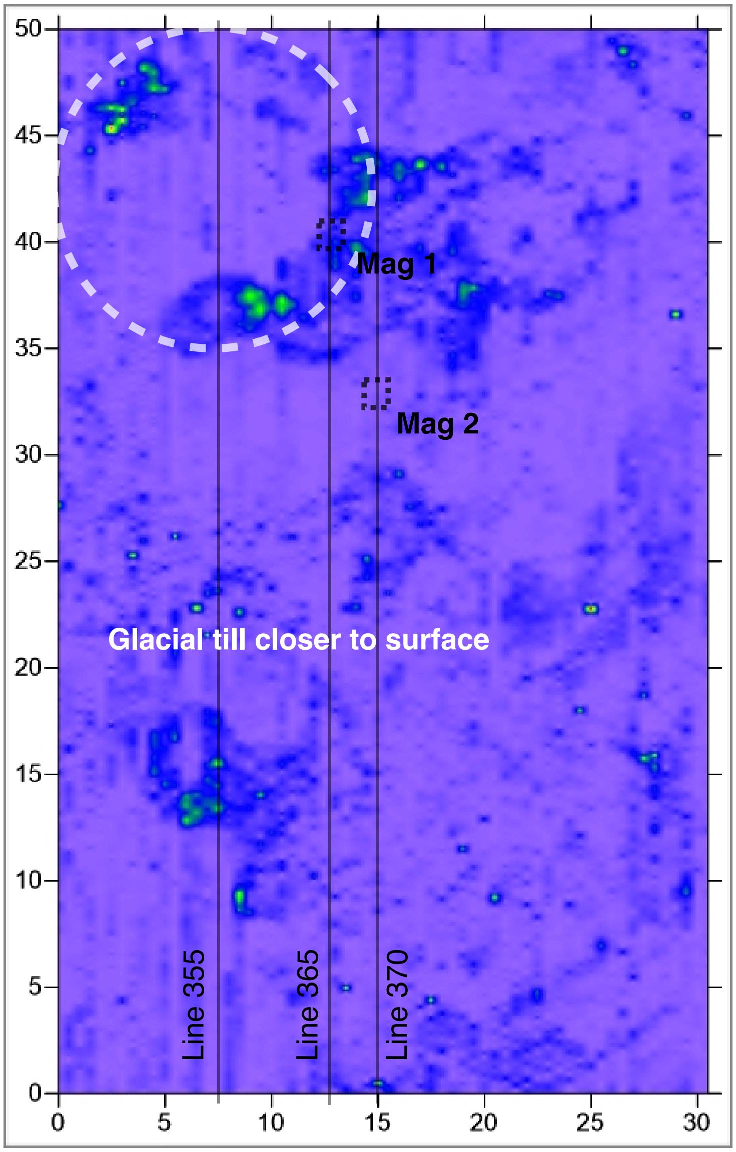


Figure 6.7: Planar view of Slice 3 (4-6 ns or ~20-30 cm below the surface) of the EfOx-80 North GPR grid.

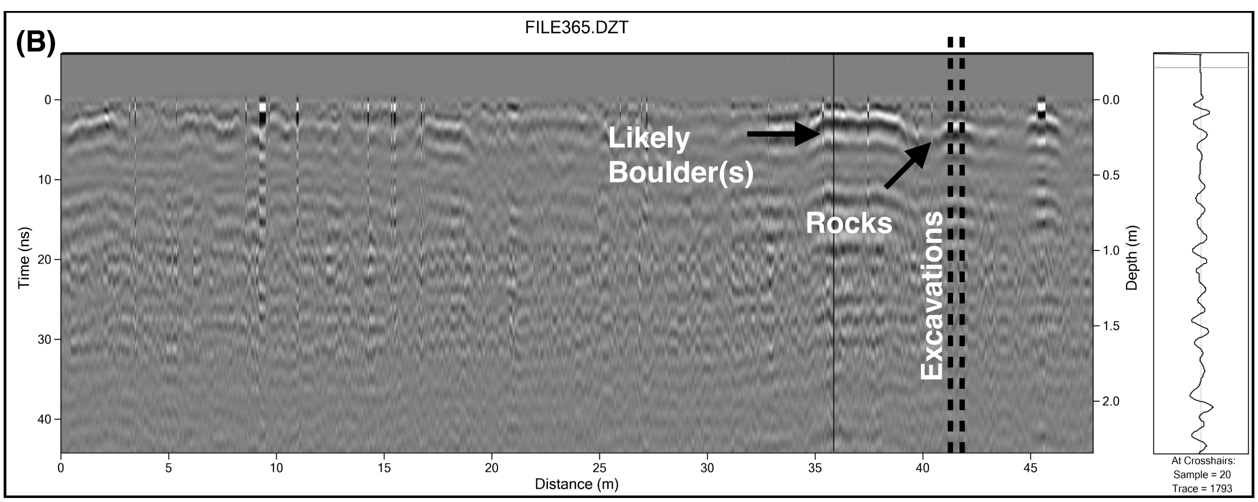
coupling from the ground and getting stuck in the up position before dropping suddenly after a bump.

In spite of these difficulties, the GPR profiles show a layer of fairly constant velocity between 20-60 cm that is even somewhat visible on the trace amplitude graph of the profiles. Between 60-100 cm seems to be a layer of increasing point reflections again, with noisy data below that, likely due to signal attenuation.

The glacial till on the surface that is visible in the magnetometry data also shows up as a cluster of point sources of varying depths in the GPR data to at least 8 ns (~47 cm) below the surface. Many of the profiles show a shallow area of high amplitude reflections just SE of the glacial till deposits that form a small (5 m) circle on the planar slices (slice 3, 4-6 ns,) in *Figure 6.7*. Its proximity to the surface till suggests that it is part of the glacial gravels, making the likelihood of it being anthropogenic lower.

The northwestern excavations at Mag 1 revealed that the compact hard brown sand went to a depth of at least 50 cm before it began transitioning to a fine — almost ashy — grey silt layer that contained increasing numbers of gravel and stones up to 30-40 cm across. The compact sandy layers and many of the rocks within it had small white concretions throughout that were collected for sampling. X-ray Diffraction (XRD) analysis— which measures how a mineral bends or diffracts light (Berkowitz 2012)— showed that the concretions were mostly quartz, likely precipitating out of the surrounding sand (Nichols to Fisher 2019, personal communication). Profile 365 in *Figure 6.8* shows the rocks excavated from near the surface of the unit.

Figure 6.8: (A) Rocks found near the surface of Mag 1 excavations in the EfOx-80 North grid visible in File 365 profile (B) at around 40 m along the line.



Excavations at Mag 2 showed that the layers of gravel and the grey silt were closer to the surface in this location, which is interesting in comparison to the GPR profile at this location. The profile of line 370 in *Figure 6.9* shows that there are some low amplitude point sources here even though the general trend along the line is that of a fairly constant velocity of radar signal, as seen in the other profiles in the grid. It may be that the majority of the rocks in this unit are too small to be picked up by the radar signal.

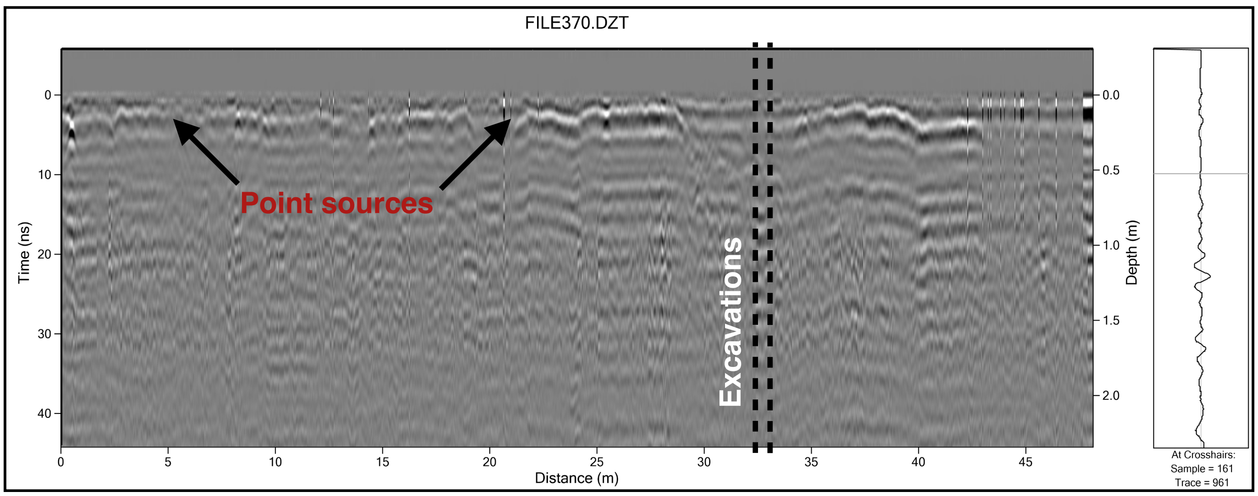


Figure 6.9: Profile 370 of EfOx-80 North showing where the excavation unit would be and some of the low amplitude point sources.

The the northwestern corner of the 4-6 ns slice (~20-30 cm below the surface) of the EfOx-80 GPR data collection grid shows a trend of low amplitude signal returns inside the area of the same possible ring visible in the magnetometry data (see page 77 in chapter 5). A small area of higher amplitude point reflections can be seen on the western edge of the ring where the possible hearth is, and there is a more scattered area of higher amplitude point sources to the east, and southeast. Other areas of low amplitude do not have the the surrounding high amplitude area, suggesting that something different is happening here. The point reflections around the area of low aptitude may represent an area swept clean of rocks and debris such as the inside of a tipi (Kehoe 1958).

The excavations at Mag 1 are just on the edge of this area of high amplitude returns. There were no artifacts excavated from these units, and the GPR files 354 and 355 showed there is not much to see in the area.

GPR Results at the Matzhiwin Creek Sites

EfOx-77

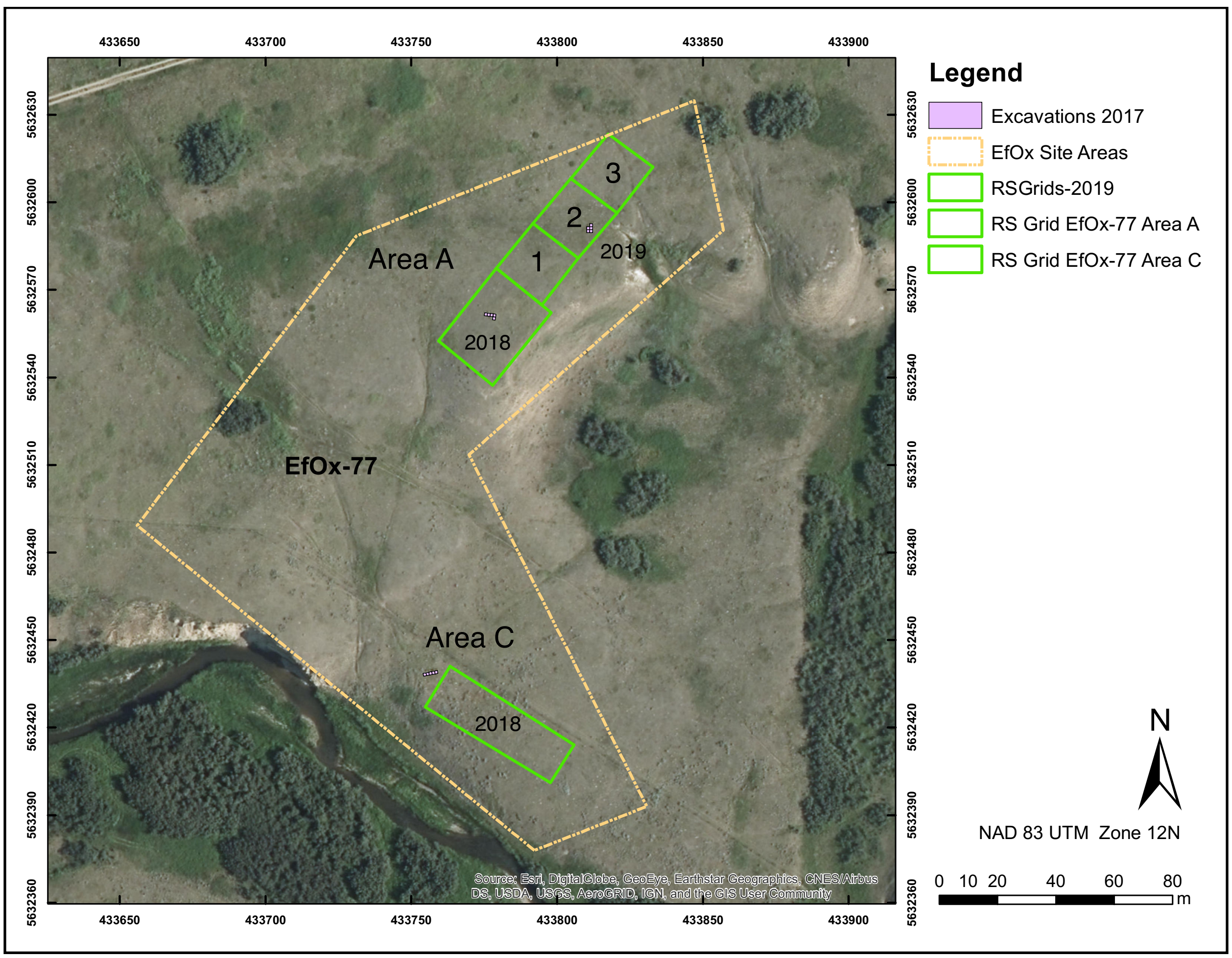


Figure 6.10: Map of the 2018 and 2019 GPR grid locations at EfOx-77.

2018 Area A Upper Terrace Grid

The GPR data for this area was collected in the same 24 by 32 meter grid as the magnetometry data (see *Figure 6.10 above* for grid locations). The grid has an elevation difference of 1.5 m from 772.0 m above sea level near the centre of the grid, to 770.5 m at the northern and western corners (according to the 2019 drone LiDAR data provided by Western Heritage). The grid was situated over the top of a sand dune that had five 1 by 1 m units excavated by field school students in 2017. The GPR data was collected on a GSSI SIR 3000 unit connected to a 400 MHz antenna mounted on a 3 wheeled cart.

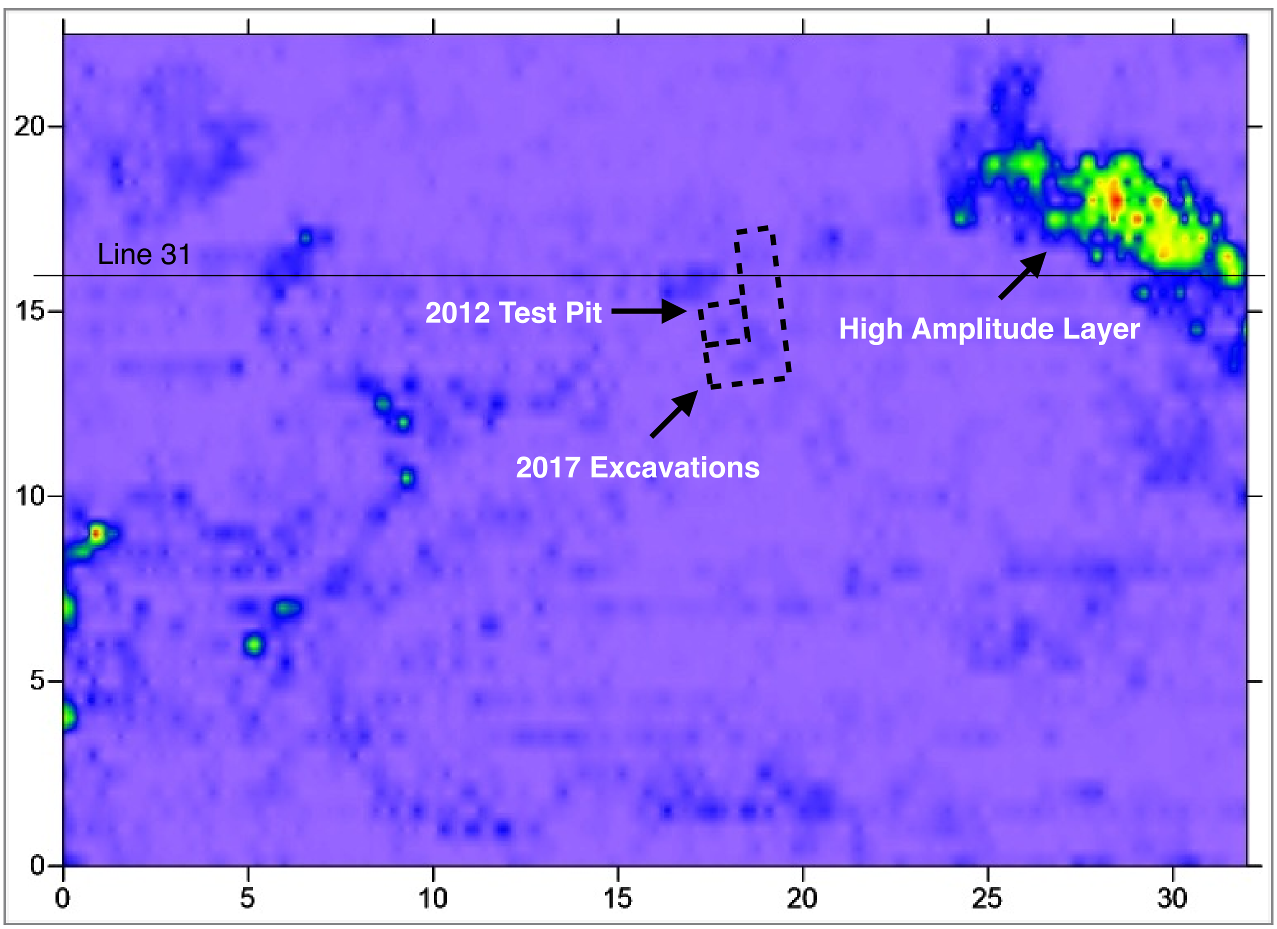


Figure 6.11: Slice 4 (6-8 ns, ~30-40 cm below the surface) of the 2018 Area A Upper Terrace grid shows the northern area of higher amplitude returns in relation to the 2017 excavations.

A few faunal remains were excavated from the 2017 units, but the GPR would not be likely to directly pick those up. The excavation units can be seen on the GPR profiles in form of higher amplitude wave recordings (visible in the plan view in *Figure 6.11*) that extend from the surface to the bottom of the profiles and locations where the antenna bumped down onto the slightly lower and looser surface of the back-filled units and then back up.

The northern-most corner of the grid collected in 2018 (about 12 m directly north of the 2017 excavation units) is one of the lowest parts of the grid, and also has the highest amplitude measurements of the grid as can be see in the upper left of *Figure 6.11*. The high amplitude velocity changes appear from 4-16 ns (0.21 m to 0.85 m below the surface) and form a distinct surface in the profiles in this area. In the profile of line 31, the excavation unit can be seen impacting the edge of this layer before it gets less distinct further to the south (*Figure 6.12* of Line 31).

The 2017 field school students report hitting a clay layer between 40 to 50 cm below the surface in their units (pictured in *Figure 6.13*). The sand above this clay was

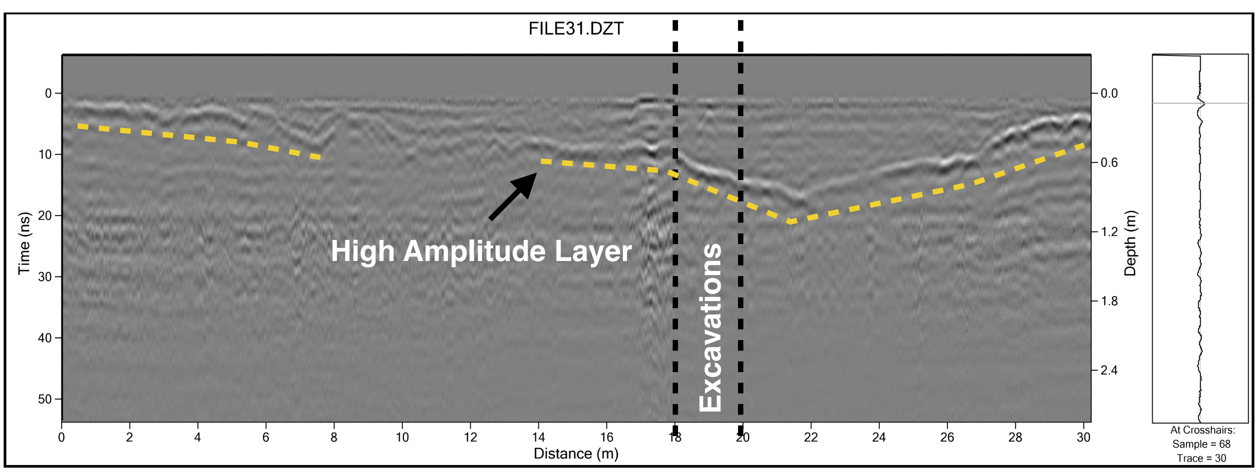


Figure 6.12: Line 31 profile from the 2019 Grid 1 with the western Area A excavation units on it, shows around the 18 m mark.

Figure 6.13: Compacted concreted surface in Unit 11 of the 2017 excavations in the 2018 grid of Area A of EfOx-77.

moist and turned white when it dried out. A couple of the students commented that the sand was fairly moist as they dug through it, as was the clay layer. When the clay was moist it was soft and not much trouble to dig through, but as it dried it hardened and became really difficult. Only a couple dozen artifacts were excavated from these units, mostly bone fragments and lithic flakes, but all were recovered from throughout the 20-30 cm layer of sand above the clay.

Given the descriptions from the excavations and the GPR results shown in *Figure 6.12*, the high amplitude reflections in the GPR data have been shown to be an extension of the clay layer that the field school students encountered. This layer continues to be visible in the 2019 GPR data collection, as will be discussed below.

The challenge with this layer is deciding its importance archaeologically. It is hard to be certain if the clay was ever a surface deposit or if it is the result of water leeching finer silt and clay particles, deposited on the surface by wind, down through the sand dunes. The one thing we can say is that no artifacts were found below where it started, but shovel tests dug in 2012 did not go any deeper than 60 cm.

<u>2019 EfOx-77 Area A Upper Terrace GPR Grids</u>

During the 2019 field school, the grid collected at area A in 2018 was expanded using the same grids the magnetic data was collected on. Field school students practiced collecting GPR and magnetometry data over three 20 x 20 m grids extending from the northeast edge of the 2018 grid. These grids cover an area 20 m wide and 60 m long that extends from the downslope of the dune peak in the 2018 grid, across a natural runoff channel that runs northwest to southeast through the second grid, and back up again on the other side of the channel. The highest point in any of the three grids is in the northern corner of grid 3 at 771.5 m ASL and the lowest is on the northwestern edge of grid 1 where it goes over the runoff channel at 770.5 m ASL. The GPR data for all three grids was collected on a GSSI SIR 3000 unit connected to a 400 MHz antenna towing a survey wheel.

- EfOx-77 Area A Grid 1

The first grid contains a continuation of the buried clay layer seen in the 2018 Area A grid displaying an upward facing lens in the profiles that looks like a buried aeolian dune in the south corner as can be seen in line 27 in *Figure 6.14*. Though soil profiling would be required to confirm it is a buried dune, the current aeolian influence on the area and what is know about its history both suggest that the layer is in fact part

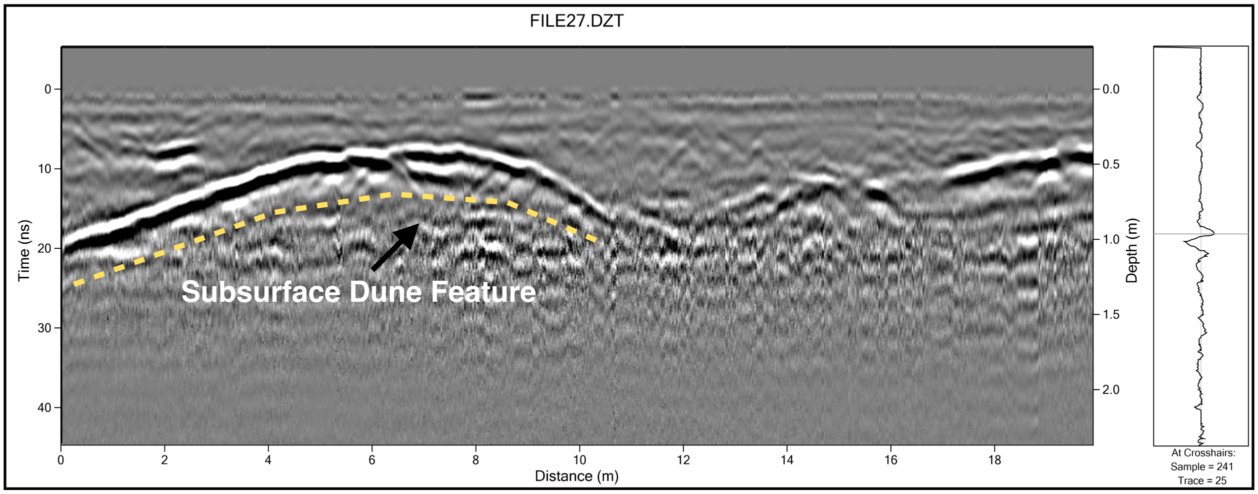


Figure 6.14: Dune feature in the profile of line 27 of 2019 Area A Grid 1.

of an old surface. Beyond the dune feature to the north and east, the layer flattens out at a fairly shallow depth of around 50 cm below the surface of the prairie.

- EfOx-77 Area A Grid 2

In the second 2019 grid the clay shown in *Figure 6.15* is very close to the surface, at least partly due to this being the lowest area for GPR data collection in Area A of EfOx-77. This is where the runoff channel really starts to become a distinct landform in the SE edge of the grid. As a result, the clay layer is never more than 0.5 m below the prairie surface in any of the profiles. Profile 88 in *Figure 6.16* shows where

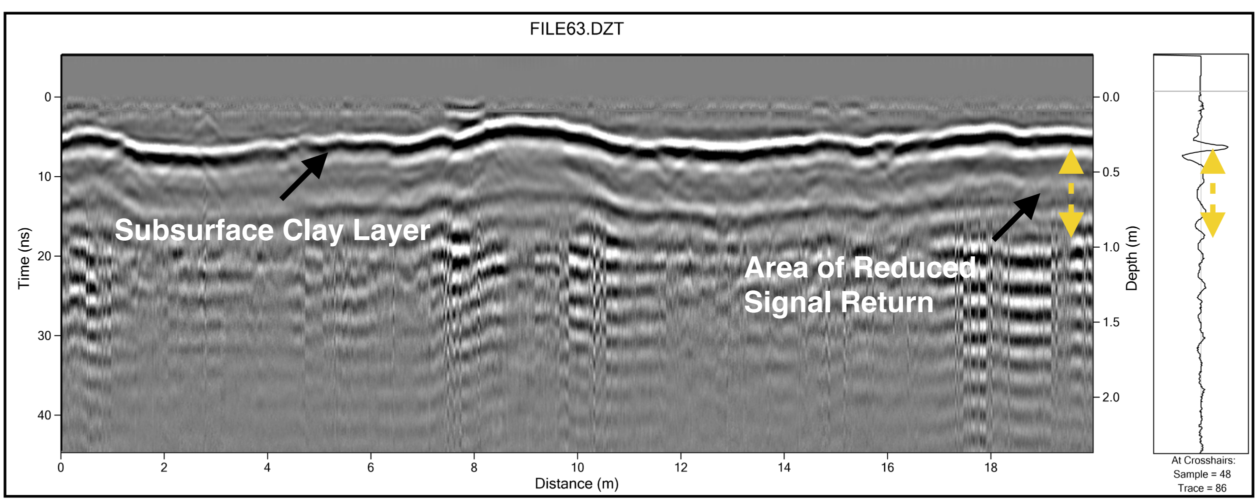


Figure 6.15: Profile from line 63 in 2019 Area A Grid 2 showing lack of signal below 0.5 m.

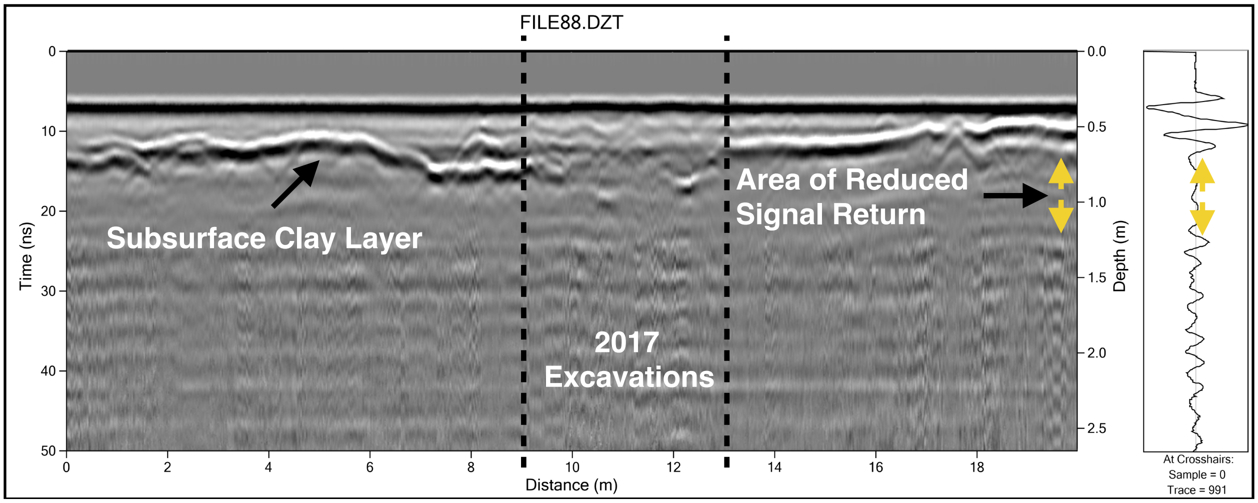


Figure 6.16: Profile of line 88 in 2019 Area A Grid 2 showing where the subsurface clay layer has been interrupted by the 2017 excavations units A2 and A3.

the the layer crossed over the northeastern set of excavation units A2 and A3 in 2019 GPR Grid 2 from the 2017 field school around 35 cm below the surface.

Below the clay there is a greatly reduced signal return and background noise that is a result either of the radar signal not penetrating the clay layer, or a fairly homogenous sand layer below it. If the signal is not penetrating the layer, it suggests the layer is clay is attenuating the radar signal away from the receiver. As with the 2018 Area A grid, all artifacts excavated during the field school in 2017 were collected from above this level.

- EfOx-77 Area A Grid 3

The clay layer continues through GPR Grid 3 at an even shallower depth and, as can be seen in *Figure 6.17*, it is very difficult to see below this layer. Some of this difficulty may be down to the inexperience of field school students collecting on a cold windy day, but like the results in the second grid, below the clay there are only background waves.

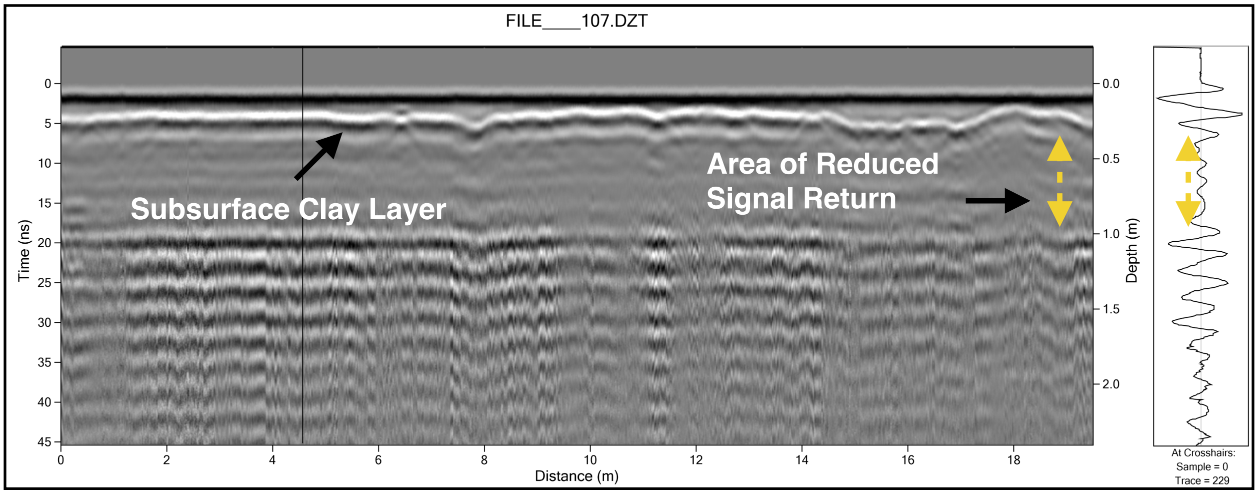


Figure 6.17: Profile of line 7 in 2019 Area A Grid 3 showing the lack of signal returns below the clay layer.

2018 Area C Lower Terrace Grid

This grid is located on a lower terrace just north of Matzhiwin Creek that was designated as Area C during the 2012 field school in the southern-most leg of site EfOx-77 (see *Figure 6.10* on page 103). The GPR data uses the same 50 by 15 m grid as the magnetometry that runs from the northwest to the southeast along the south side of a fence line marking the southern border of the Mattheis Ranch. It is about 35 m north of where the creek currently runs and is on a flat bench about 8 m above the creek level. The surface of the grid is very flat with only a 0.5 m difference in elevation across the whole area but is interrupted by sage brush in the westernmost corner. The area was chosen for geophysics because excavations conducted in 2017 returned faunal remains and lithic artifacts mostly in the form of flakes and fire broken rock.

The effects of the sage brush in the GPR profiles can be seen in line 68 shown in *Figure 6.18* at about 26-29 m and again at 41 to about 44 m. In these locations the antenna had to either go around or over the sage brush and as a result the ground

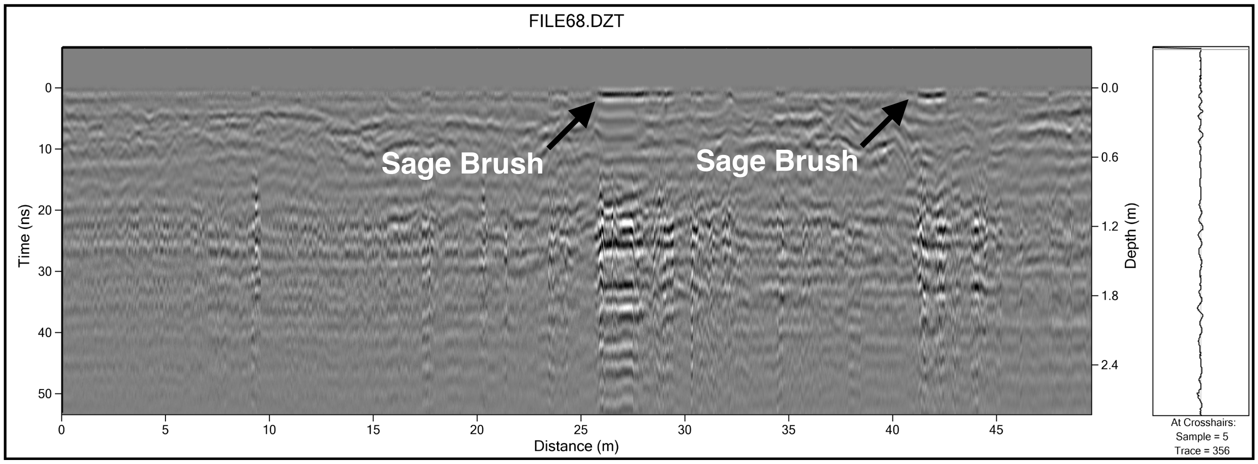


Figure 6.18: Profile of line 68 in 2019 Area A Grid 2 showing where the equipment had to go around/over sage brush.

coupling being lost, producing an effect that can be seen right to the bottom of the profile. An old excavation unit and issues with the in the cart create similar signals.

Excavations west of the geophysics grid carried out by field school students in 2017 proved to be mostly clay sand and silt with some inconsistent paleosols recorded in the first 50-65 cm below the ground surface. These paleosols do not vary enough in density from the surrounding sand to create a noticeable impact on the radar signal. The upper portions of both the profiles, as in the 5-6 ns (40-50 cm below the surface), and planar slices show a fairly homogenous upper layer except where there are surface interruptions.

Culturally, there is nothing directly visible in the GPR collected in Area C. Bone was excavated out of the units west of the GPR grid but is unlikely to be seen by the radar waves for two reasons: 1) the density and makeup of the bone is not significantly different enough from the surrounding sand to create a velocity difference large enough for the GPR receiver to recognize; and 2) the wavelength of a 400 MHz antenna in this sand with a Relative Dielectric Permittivity (RDP) of 8 is about 25 cm. This means

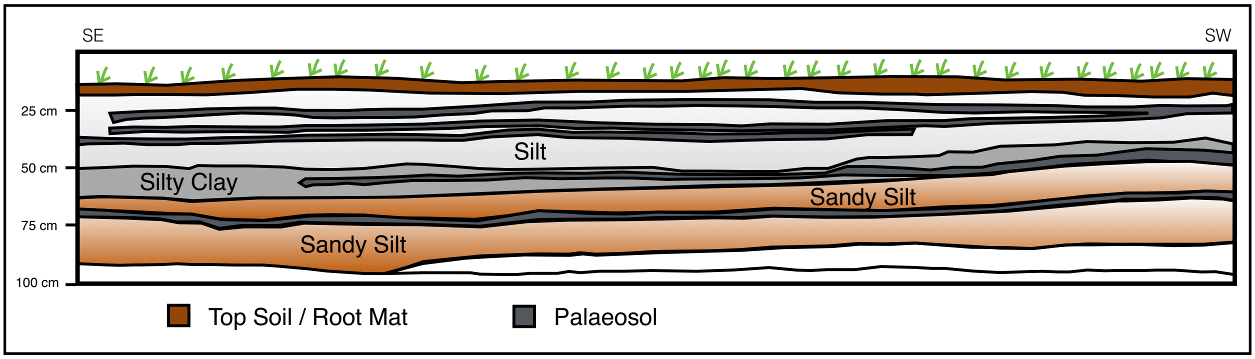


Figure 6.19: Stratigraphic south wall profile of the 2017 C1-C5 excavation units northwest of EfOx-77 Area C GPR grid.

objects below the surface must have dimension of 25 cm or larger to be visible in the profiles or plan views of the GPR data. These limitations also apply to the palaeosols identified in the excavation units.

The “silty clay” layer in the profile in *Figure 6.19*, however, does make an impact on the radar profiles. There are higher amplitude reflections at a depth of 6-14 ns (30-80 cm below the surface) depending on where in the grid measurements are taken. While no profiles are available of any area within the GPR collection grid, there are profiles recorded of the 2017 excavations 2.5 meters west of the grid edge.

The profile grids of excavations at area C show a discontinuous “Silty Clay” layer at a depth of 50-65 cm below datum, or about 37 to 53 cm below the surface and below

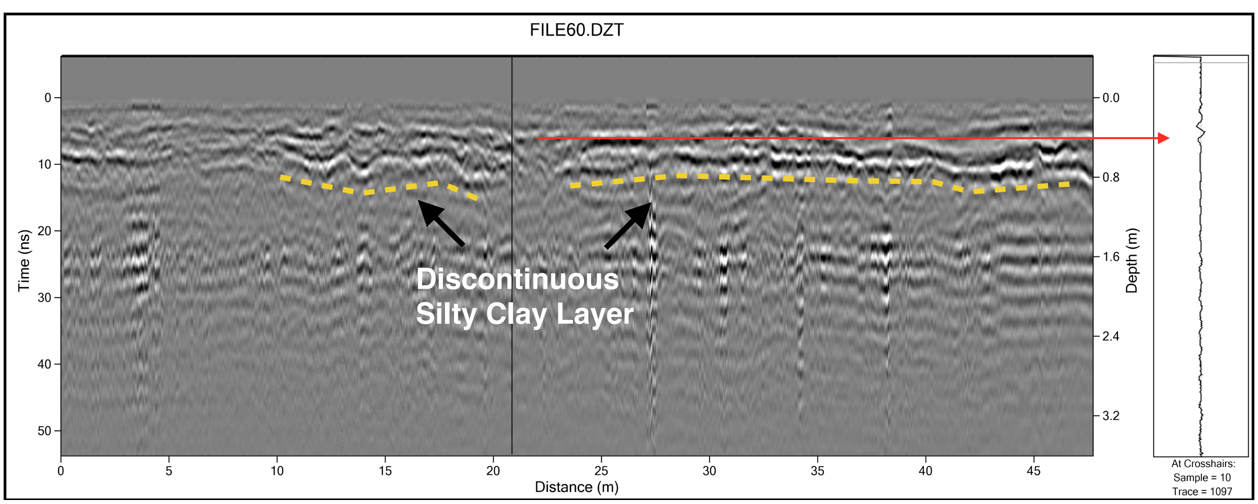


Figure 6.20: Line 60 of EfOx-77 Area C showing the discontinuous silty clay layer.

that is "Sandy Silt." Excavation records describe encountering the silty clay layer saying the "Sediment became difficult to trowel and much drier than previous layers…" (C. Johnson on Level 10 in unit 5 form) and further that the "Sediment was dry and compact." (C. Johnson on Level 11 in unit 5 form). The fact that the clay layer is more compact and difficult to dig through than the mostly silt layers above suggests that the changing density created a radar wave reflection with a distinct change in amplitude.

It is interesting that the clay layer thins or disappears so that it is not picked up by the GPR near the middle of the southeast half of the grid but picks up again towards the eastern edge as shown in *Figure 6.20*. The fact that it is not a distinct flat layer may indicate that it has been churned up, maybe by frost action or by previous deposition and erosion process of Matzhiwin Creek. The 2 through 12 ns slices in *Figure 6.21* progressively show where the clay layer peters out in the eastern portion of the grid.

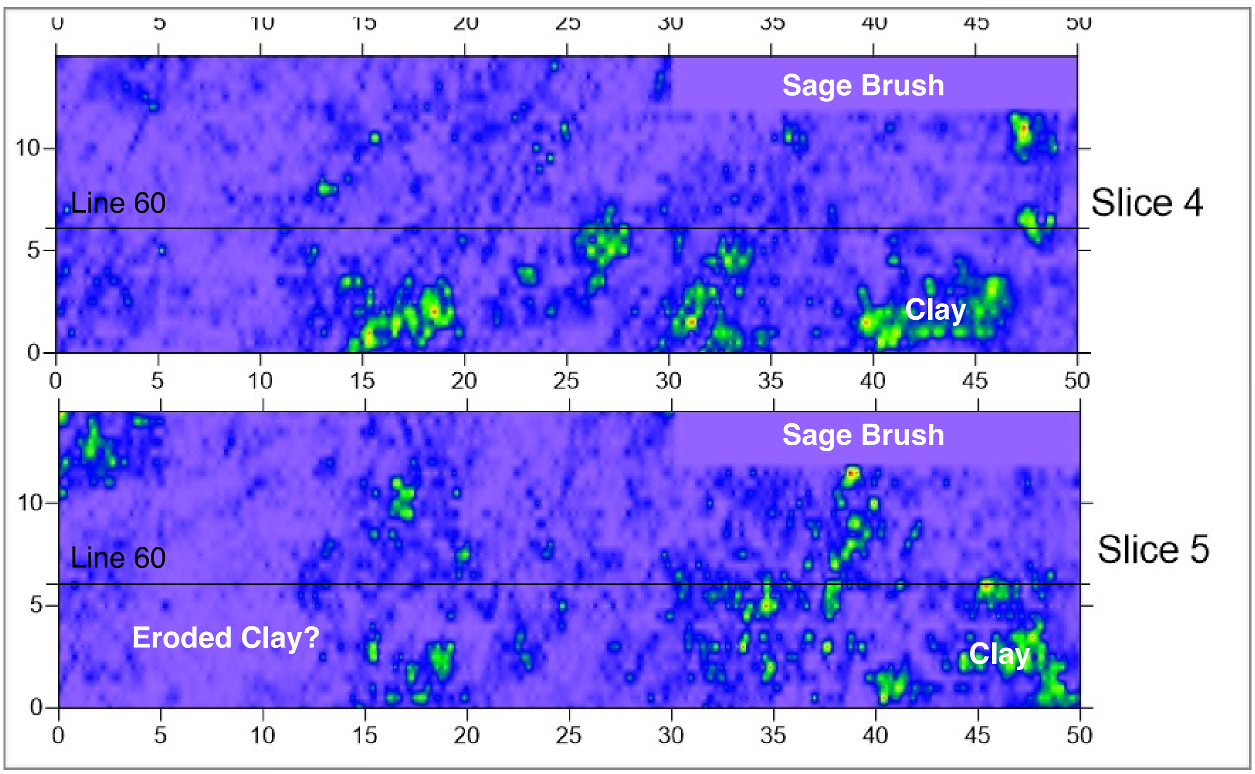


Figure 6.21: Slices 4 (6-8 NS) and 5 (8-10) of the data from EfOx-77 Area C GPR Grid showing where the clay inclusions may have been been eroded.

EfOx-70

On May 24, 2019 a small 2.5 m by 10 m grid was set up over the proposed excavation area at EfOx-70 before the field school students began excavation. As shown in *Figure 6.22*, the grid ran 10 m along the upper edge of the steep south bank of Matzhiwin Creek where it is crumbling into the river. The width of the grid back from the creek bank was seriously constrained by sage brush growing on the south edge of the grid that later became where the excavation back dirt was piled.

Data was collected in lines all running from east to west, 50 cm apart within the boundaries of the grid. Planar data of this grid proved to not be very useful due the

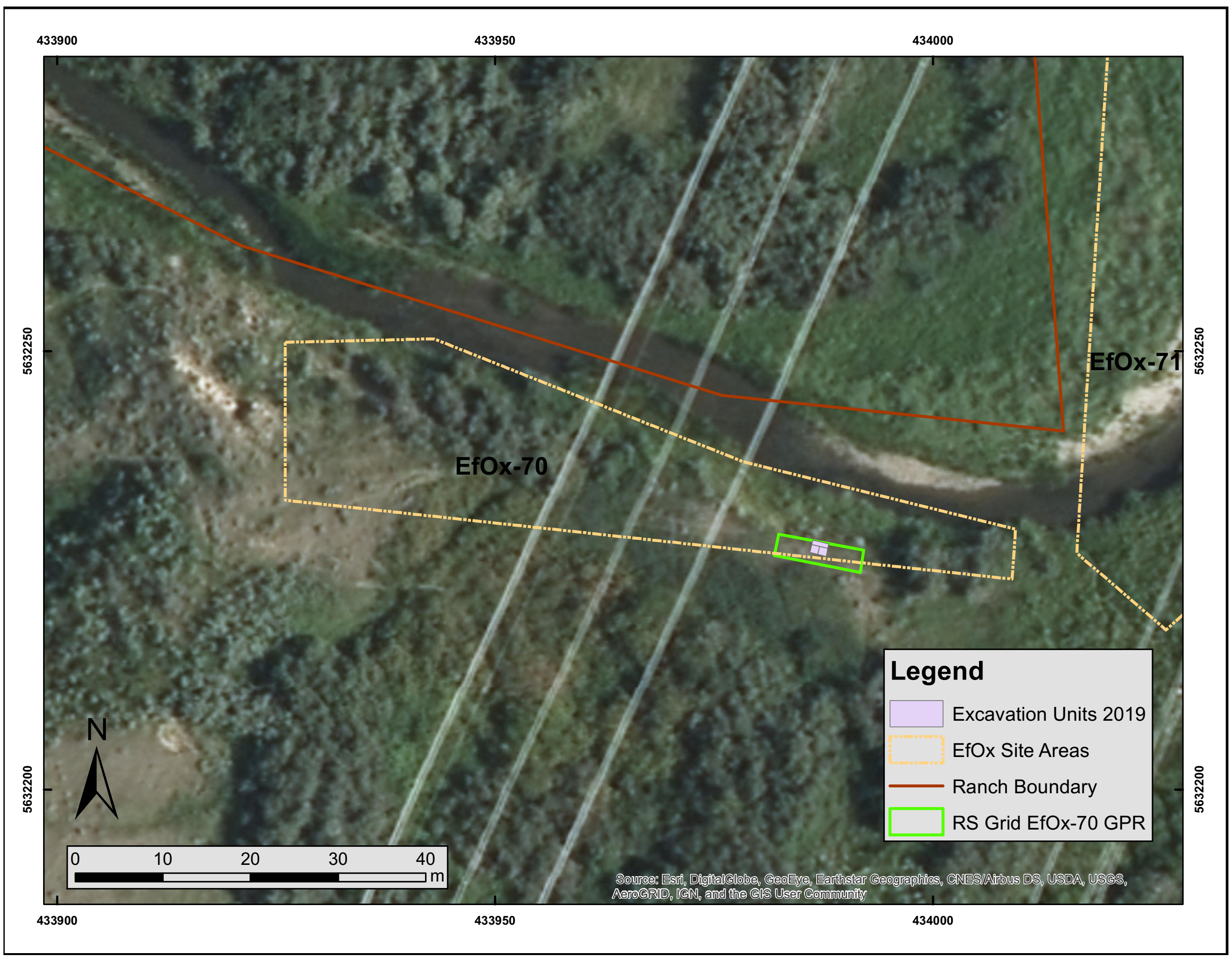


Figure 6.22: EfOx-70 GPR grid location and excavation units.

narrow nature of grid. Only 5 lines of data (2.5 m wide) could be collected in that direction. This may have been improved by the collection of GPR lines every 25 cm, especially compared to the 50 samples per meter (every 2 cm) that the unit collects along a GPR line.

Profiles of the GPR data show evidence of how the sandy bank of the creek was formed. The tops of the profiles look like a swale from the west rising up to the east, as can be seen in line 4 in *Figure 6.23,* suggesting wind blowing sand up a dune from the west. These reflections are likely coming off a faint palaeosol visible in the top 20 cm of the excavation units that gets closer to the surface as it extends to the east.

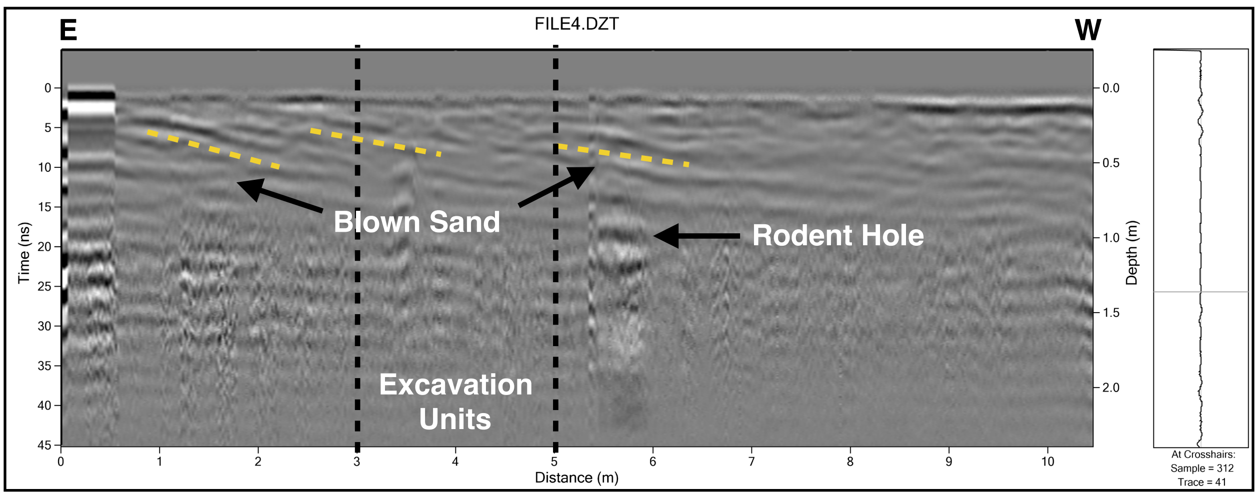


Figure 6.23 Profile of line 4 over EfOx-70 GPR grid shows blown sand and the rodent hole with gains increased to emphasize small changes in velocity.

A shallow bowl roughly 2.5 m wide shows in the profiles in the southwestern part of the grid that is especially visible in lines 5 and 6 (see *Figure 6.24* for example) that might be the result of a buffalo or cattle wallow. This would likely be part of the same palaeosol that has also been covered by the aeolian sands.

The line collected closest to the creek bank in *Figure 6.25* shows several columns of cluttered reflections of the soils at deeper levels below 1 m below the

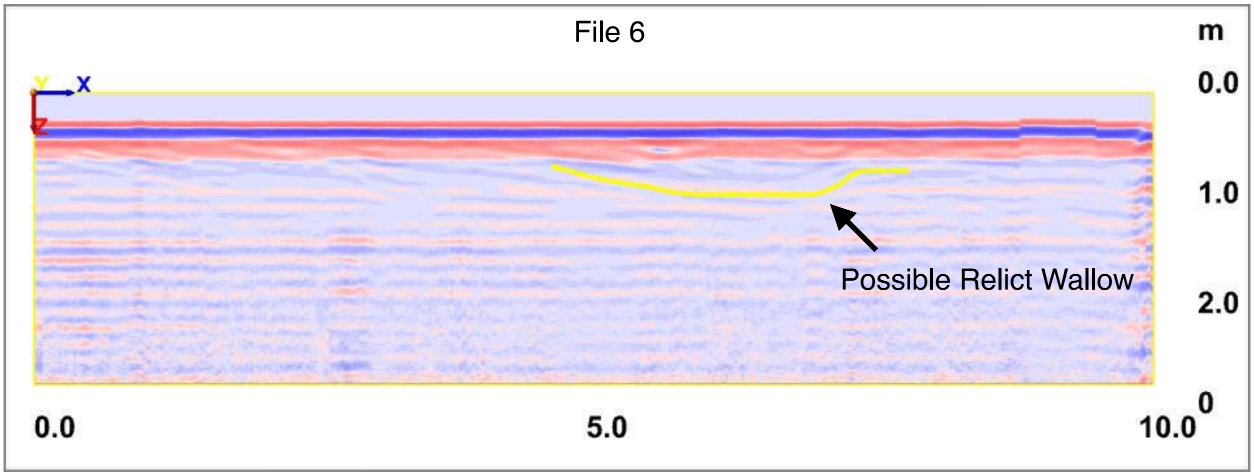


Figure 6.24: Line 6 in the EfOx-70 GPR grid shows the location of a possible relict wallow. (RADAN 7 profile)

surface. This is likely the results of the slumping occurring at the base of the bank where unsorted soils have come to rest after falling off the bank above where the radar signal is returning from traveling though a combination of clods of fallen sand, soil and air.

There is also evidence of a rodent hole that turned up in the excavation in the GPR line 4 (*Figure 6.23*) that went over it on the western edge of excavation unit 1. The edge of the rodent hole can be seen in the west wall of the excavations in *Figure 6.26*.

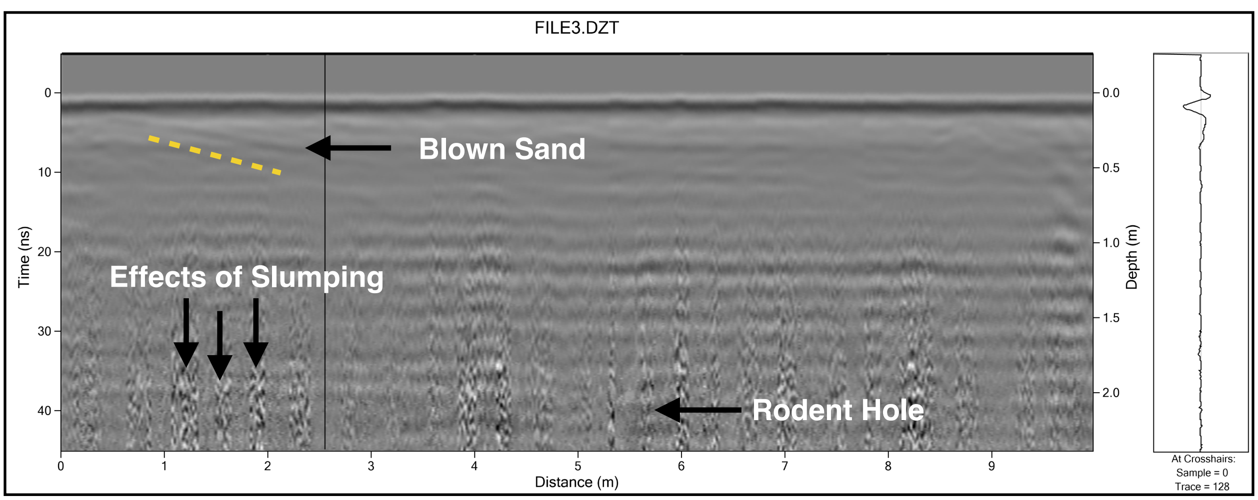


Figure 6.25: Profile of line 3 of EfOx-70 GPR Grid with gains increased to show the effects of the slumping and creek bank on the GPR.

Figure 6.26: Rodent hole on the edge of the 2019 excavation units at EfOx-70.

In the lower levels of excavation at EfOx-70, below 110 cm below surface (BS), the bone bed pictured in *Figures 6.26* and *Figure 6.27* became apparent with densely packed skeletal remains of bison mixed into the silty/sandy matrix. The top 20 cm of this bone layer proved to be fairly routine, but below that the bone became increasingly fragile and crumbly to the bottom of the bone layer at approximately 175 cm BS.

One of the bones in this bottom layer was sampled and submitted for XRD analysis (Nichols to Fisher 2019, personal communication). The results show the sample to be a mixture of mostly Hydroxyapatite, as is to be expected, as it is a major

Figure 6.27: Bone Layer in the south wall excavated from Units 1 and 2 at EfOx-70.

mineral in the formation of bone. The remaining portion of the sample is made up of higher amounts of brushite, calcite, gypsum and barium zirconium phosphate. The deposition of these minerals is likely a result of water rising and leeching minerals out of the bone layers. The presence of the Brushites prismatic crystal structure is likely what made the bone samples seem to sparkle in the sunlight.

The gypsum is notable because it retains moisture and the GPR signal does not react the way it does traveling though the other soils in the profiles. The “[p]ropagation velocities for all gypsum-rich soils are well above the trend line established for gypsum-free soils. Likewise, attenuation rates are lower than expected for the level of soil moisture found in these samples.” (Koh and Wakeley 2011; 1053). This means radar waves travel faster through gypsum-rich soils and are less likely to lose energy as they travel. This is reflected in the GPR data in *Figure 6.28* in that the data below about 90 cm below the surface trends toward stabilization in all of the profiles with very little change in signal velocity.

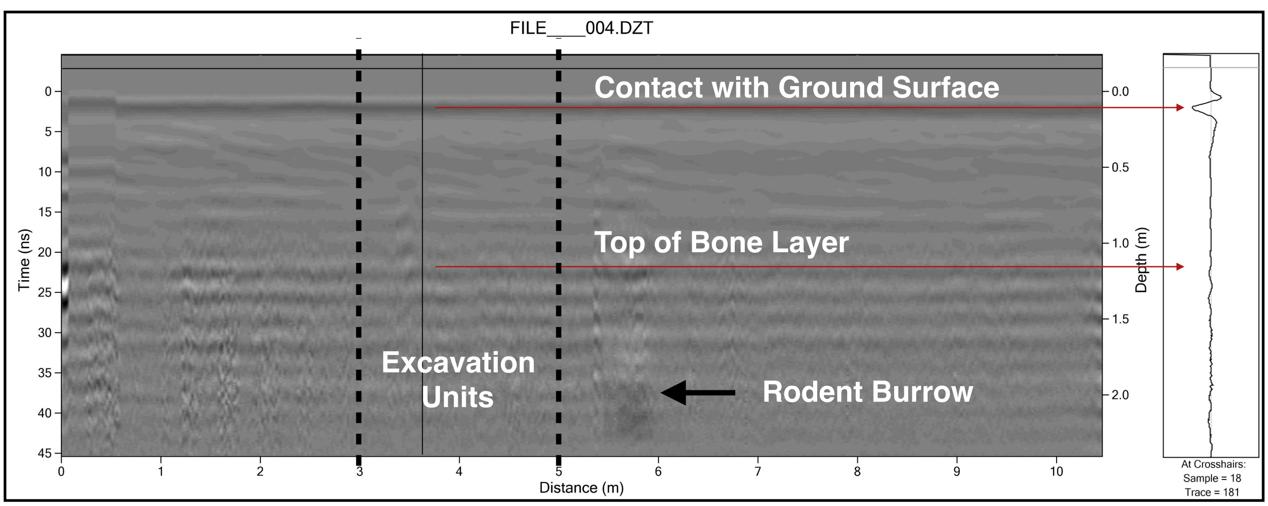


Figure 6.28: Profile of line 4 at EfOx-70 with no gain adjustment. Note that the profile shows almost no change in velocity except around the rodent hole.

EfOx-71

GPR data was also collected at EfOx-71 before the 2019 field school excavations began (see *Figure 6.29)*. Here, a grid measuring 5 m by 5 m was set up as close as possible to the east bank of Matzhiwin Creek covering excavation units 2 and 3 after they were laid out but before excavation began. This grid was limited partly by the irregular edge of the creek bank to the west, and partly by the time available for survey before excavation began. All the GPR profiles were collected in the same direction running from roughly north to south through the grid.

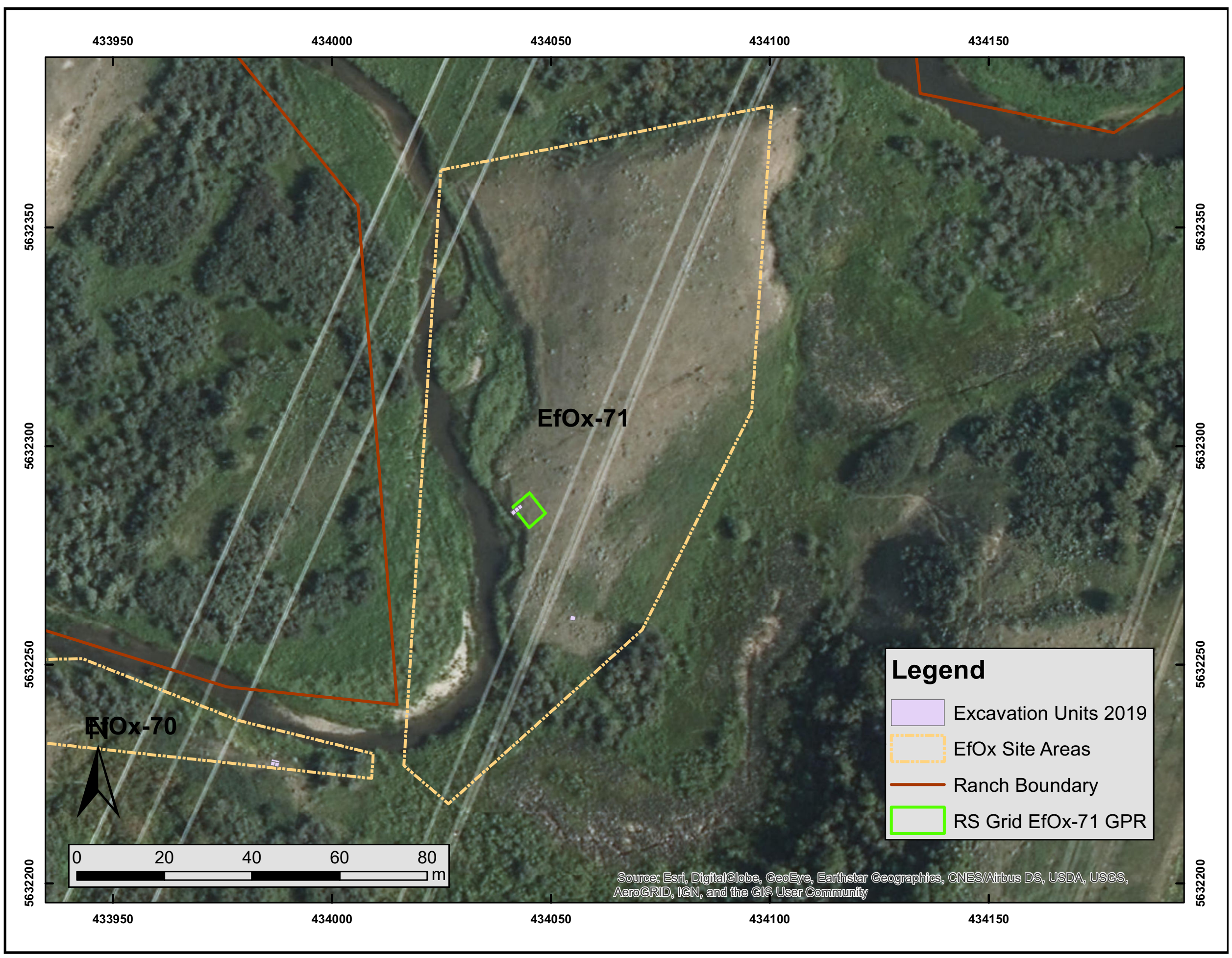


Figure 6.29: Map of EfOx-71 showing GPR grid location and excavation units.

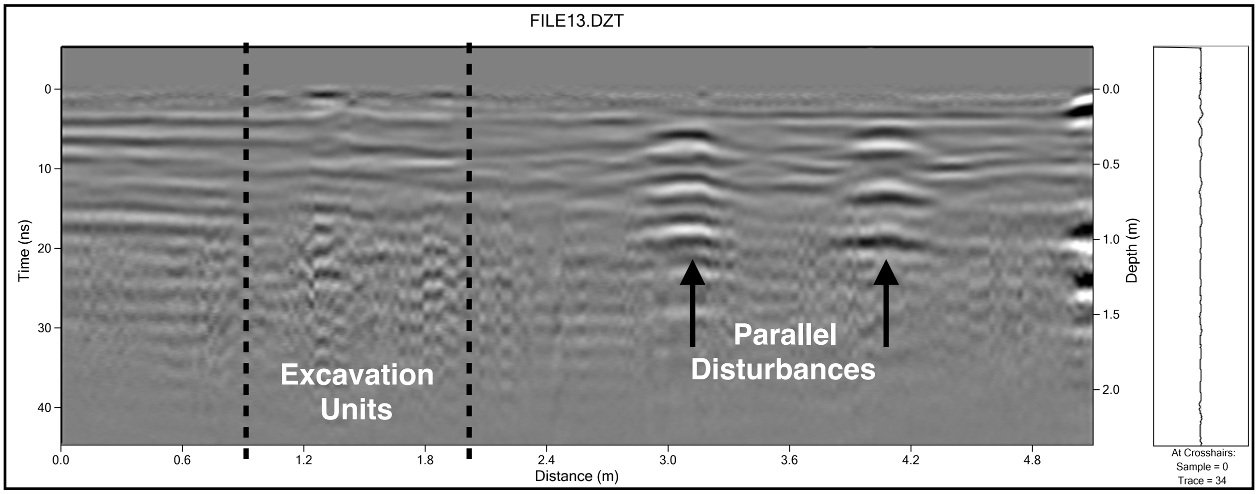


Figure 6.30: Profile of line 13 showing the hyperbolas.

There are some definite disturbances in the ground visible as hyperbolas in the profiles of the first 5 lines as shown in line 13 in *Figure 6.30*. They are roughly 2 and 4.5 m south of where the excavation units would be placed. When viewed in the planar grids such as the 6-8 ns grid shown in *Figure 6.31*, it becomes clear that there are a pair of higher amplitude reflection lines that run parallel through the southern portion of the gird from WSW to ENE, with the southern one extending further east. They are quite shallow, beginning at no more than 30 cm below the surface, and no trace of them is visible on the surface. They are about half a meter too narrow to be buried vehicle tracks as they are only about a meter apart. It

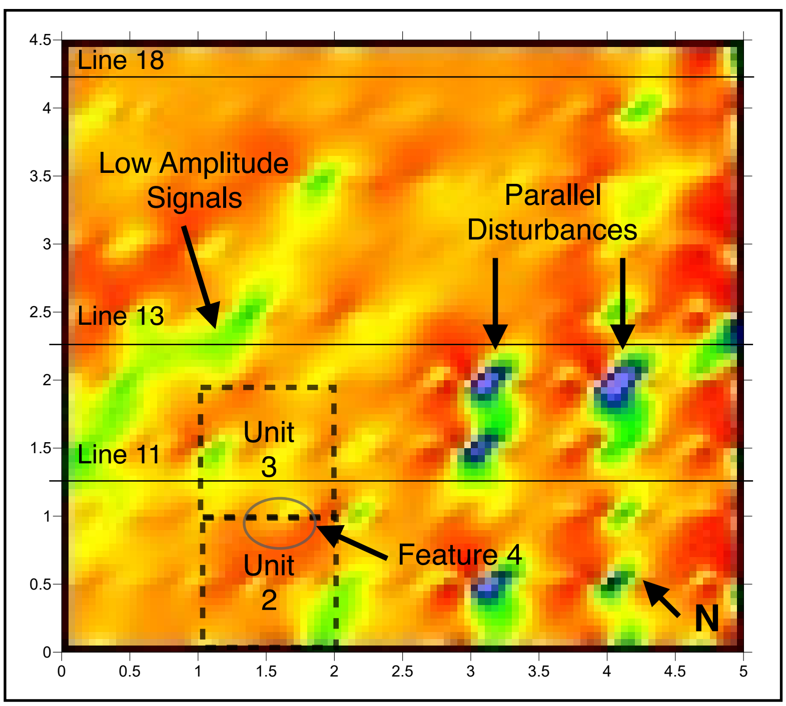


Figure 6.31: Shaded relief of gridded slice 4 of the 2 ns (6-8 ns) slices, with the excavation units shown.

is possible that they are old waterline excavations running water from the creek to irrigation apparatus or cattle troughs as can be seen upstream on the creek to the west.

Some very subtle low amplitude disturbances in the profiles occur right around the 50 cm below surface mark in the northern ends of the lines that run though the excavation units. There are very subtle disturbances in the profiles of lines 10 and especially 11 (shown in *Figure 6.32*) that correspond with the location of excavated Feature 4, a bone upright feature with evidence of charred soil and fire broken rock. The charring in feature 4 would likely have given a more significant result on magnetometer data, if only the power lines were not directly over this site. A similar disturbance can be seen in profile 14 at the same depth and it would be interesting to see if any further bone deposits would be located if the excavation were extended one more meter to the east of Unit 3.

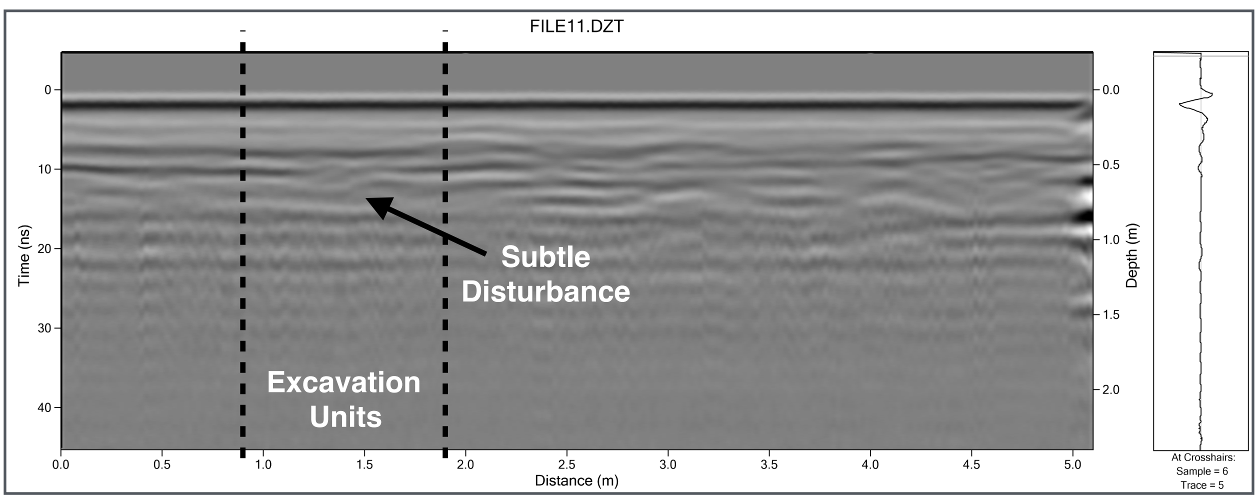


Figure 6.32: Profile of line 11 showing areas of higher amplitude in the area of Feature 4.

Two subtle areas of higher amplitude reflections between 1.25 and 2.5 m along profile 18 (*Figure 6.33*) at about 75 cm deep may be buried paleosols or other features of compacted soils. They are unlikely to be rocks, because the low amplitude of the

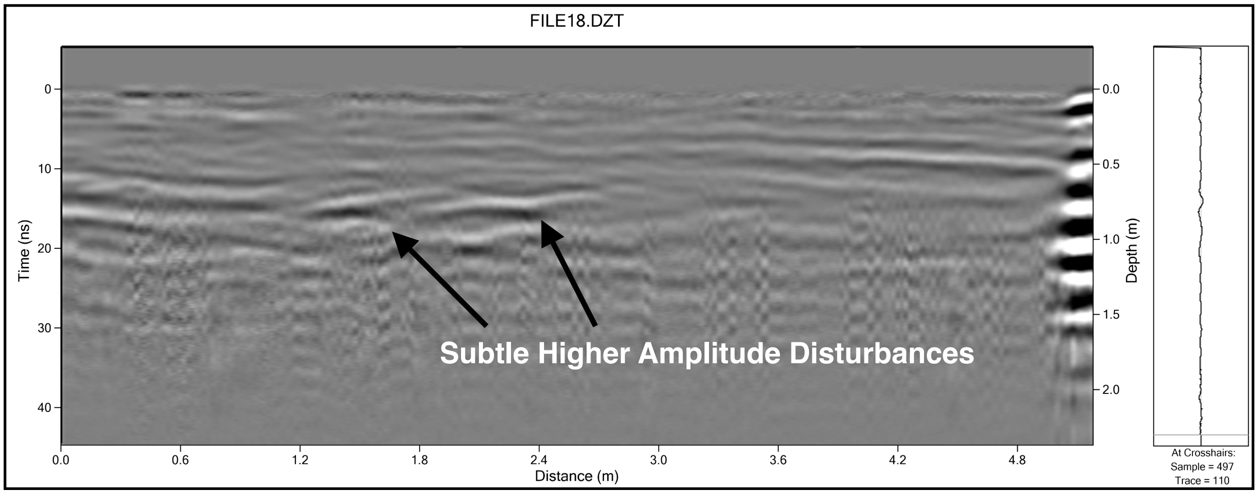


Figure 6.33: Profile of line 18 showing subtle areas of higher amplitude.

disturbances does not reflect the major change in velocity that would occur if the wave went from traveling through silty-sandy soils to solid rock.

Aside from the two shallow parallel lines, the amplitude reflections in the profiles are generally pretty flat, suggesting deposition at the bottom of water through settling. The profiles and the grids all show very little change in the radar signal aside from those instances pointed out above, suggesting they are formed in fairly uniformly laid down silty or sandy soils throughout.

Below 0.75 m the GPR profiles show similar results to EfOx-70 where there was gypsum in the sand that retained water and therefore caused only very small changes in signal speeds. The results here may be due to a similar change in the makeup of the sand, but are more likely due to their proximity to the water table. The ground is here about 1 m closer to the creek than at EfO-70 so it is likely more regularly saturated and would not need the gypsum content to retain the water and create the same effect.

Conclusions

The GPR faces many of the same problems as the magnetometry at the Red Deer River sites. The varying rock size of the glacial till, from pea-sized to boulder, makes anthropological features difficult to separate from the natural deposits. It would be interesting to see if GPR data collected over the surface ring at in the EfOx-80 south grid show any of the patterns—in the form of higher amplitude reflections around the possible ring, and the absence of reflections inside of it—that are seen in the north grid.

At the Matzhiwin Creek sites the GPR data proved to be especially useful as the magnetometer could not be used at EfOx-70 and EfOx-71 because of the overhead power transmission lines.

Although the GPR did not reflect off the artifacts directly as might be hoped, the 400 MHz proved to be a good antenna. It gets good depth penetration in the sand at the Matzhiwin Creek sites—when clay is not in the way—and its ability to resolve smaller features identified intriguing point reflection patterns at EfOx-80 along the Red Deer River. Longer wavelengths might get to lower depths, but may only show stones too large for use in a tipi ring.

The GPR provided a possible way of tracking the bone bed excavated at EfOx-70. It also provided useful information regarding site formation and processes on both sides of the creek suggesting that GPR may show its best use in geoarchaeology by expanding the reach of small excavations and profiles to much larger areas. With a landscape approach, geophysics is especially relevant as it looks at and fills in the spaces between the excavations.

Chapter 7 - Discussion

There were several lessons learned from this work, both about the individual technologies employed and how much more information is available when they are used together. This led to some intriguing suggestions for future work both on these sites, and how to approach other sites on the Northern Plains.

Remote Sensing and Geophysics Results

Currently, aerial data in the form of satellite imagery and LiDAR DEMs are pretty standard go-to references for archaeology in Alberta—and they absolutely should be—as they provide valuable context. Satellite imagery is easily accessible through ArcGIS and Google Earth, or via free or purchased download. LandSat Imagery is available for free download for most of the planet for the last 50 years. There is a long history of air photos in the province available from Alberta Sustainable Resource Development and LiDAR has been collected alongside air photos since the 1990s. The lowering of drone prices and the improvement in camera and other sensor technologies will only see the use of this technology grow as it can quickly provide data specifically designed on a project-by-project basis. But what about the geophysical methods of Magnetometry and GPR?

Near Surface geophysical techniques are not as universally useful as aerial data, and the equipment not as readily available as UAVs or drone, but they have been shown to still be well worth including in certain research designs. On most wide open fields of the Alberta Plains with minimal barriers, magnetic gradiometry and GPR can be especially useful where there is a good understanding of the surficial geology and its effect on the equipment.

Aerial data

Aerial and satellite data are best for landscape views of the connections between sites. Today's instruments are capable of making visible smaller landscape features such as relict shorelines of glacial lakes and small rises and knolls in muskeg and many other features that people have taken advantage of throughout history. Current airborne LiDAR collected by plane is available for most areas of the province. The provincial archive of air photos makes detailed imagery for the last century fairly accessible; alongside satellite imagery such as the Landsat satellites, a history of landscape change for the last 50 to 100 years can be pieced together. This detailed bird's eye view of the land offers insights at a glance about the locations of resources, convenient travel corridors and promising camp locations.

Results at EfOx-80 with the drone images flown in 2019 showed that anything visible on the surface is visible in the images if the resolution is high enough (see *Figure 4.17* on page 64). The imagery proved to be important because the rocks that form cultural features are generally too flush with the ground and grass to be visible in the DEM data, though this may change with drone mounted LiDAR data collection. Further imagery was flown in the fall 2020 to expand the area of collected data, and based on that, spring was determined to be a better collection time than fall as there is increased contrast between the green grass and the reflective stones. The dry grass pictured in the fall washes out the effects of the stones. The higher flight altitude of the 2020 flight led to a lower resolution of 4 cm per pixel compared to 1.5 cm per pixel in the 2019 data. Between the two flights, the technical results of the drone imagery were intriguing enough that a research project has been started to see if image classification can be done on the rocks to look for patterns that can later be ground-truthed as was discussed in chapter 4 (page 67).

While no further cairns were confirmed from the drone imagery, finding more of them either towards the wetlands in the northwest, or on the fields to the south, would help confirm whether Matzhiwin Creek was being used by communities as a jump or a pound. At the tipi ring sites, more extensive imagery might help to map camp locations and patterns of tipi setup. Determining how many tipis were set up at any one time, would require further inquiry into dates and whether camps were occupied once by many people, or several times, by a few.

Magnetic Gradiometry

The magnetometer was hampered a bit by the glacial gravels along the Red Deer River upper valley margin, nevertheless the results at EfOx-80 showed there is likely enough difference in the gradiometer readings between natural and cultural phenomena that archaeological features can be identified. A possible tipi ring in the north grid and the area outside the known ring in the south grid show promise. Those two features would require work beyond what was possible in this project, but could be tested in future work. Extensive excavation of the possible ring feature (likely with little artifact return) would be required to confirm its anthropological origins. In the south grid, soil testing in the area of interest to determine whether it is a natural feature of the glacial gravels, or if it is perhaps somewhere hides were pegged out to dry in the sun would be required.

The problem for the magnetometer in the north grid of EfOx-80, was the presence of naturally magnetic cobbles masquerading as hearths. It is possible that once the University of Alberta labs open again the magnetic susceptibility of the cobbles could be tested and then compared to the magnetometer results to confirm they are the cause of the anomalies recorded and whether they have a remnant or induced magnetism. Remnant magnetism would suggest that the rocks were fired to their Curry temperature, possibly in a hearth.

Fortunately, these stones at least gave a clearer understanding of what kind of anomalies to look for in the magnetic results that might be hearths, especially those hearths that do not make use of rocks, but are just on the bare soil. Hearths should have roughly equal positive and negative gradiometric anomalies—which these anomalies had—that align roughly with the north and south poles of the earth's magnetic field—which these did not. They are aligned more to the NW to SE. As previously discussed, hearths tend to be natural gathering areas at campsites even now, as they are a source of heat and light. A hearth location outside a ring might indicate summer camp vs. a winter camp when the heat would be needed indoors.

The electrical transmission lines over EfOx-71 made assessing what is probably the best site for magnetic returns, impossible. If EfOx-71 represents the secondary processing area of a bison kill of a minimum of 18 animals (Fisher 2020), there is probably a lot more to find there in terms of hearth features, middens, boiling pits and other refuse. Extended magnetometry data collection in 2019 at EfOx-77 showed that there is one possible hearth feature that could be tested in the future.

Magnetic gradiometry shows promise where it can be used on pre-contact sites. The difference between the magnetic results at EfOx-59 and EfOx-80 show that the features of archaeological interest have a higher gradiometric difference from the surrounding geology than the naturally magnetic rock in the glacial gravels. When properly interpreted and tested, magnetometry shows the best opportunity of showing the actual archaeological features and the relationships between them, especially when in combination with some form of aerial data.

GPR

The GPR did not offer much insight at the Red Deer River sites, but it confirmed that there is something going on at the location of the possible ring at EfOx-80. GPR results there showed that there are some sort of physical objects in the same location as the magnetometry data and even closes the ring a bit further on the east side. There was also a possible pit feature identified at EfOx-59 that may be natural, or cultural.

The Matzhiwin Creek sites had more interesting GPR results. The concretion layer below the excavated artifacts suggests that the dunes at EfOx-77 were stabilized when site was in use, but sand has since been accumulating, suggesting that a similar dune landscape to what we see now existed when the site was in use. Potentially the concretion layer could be mapped to give a sense of the landscape in the past.

The EfOx-70 data show effects of gypsum precipitated by the unique conditions generated by the butchering event and seasonal flooding of the creek. GPR data collection might not work as well south of the established grid because the distance from the creek water might not produce enough gypsum to create a noticeable effect. There is also the problem that the the deposits likely get deeper below the surface in this direction due to the erosion of the hill above, though the sand is an excellent medium for GPR. The area is also covered in sage brush that would have to be removed to be able to properly couple the GPR antenna with the ground. Data collection could continue farther along the creek bank to the east and west to see if gypsum-impacted GPR results runs out about the same place as the eroding bone does.

EfOx-71 offers a good opportunity to see what the GPR can do as the surface is actually fairly clear of sage brush with only short grasses and some brush along its southern edge. This might be a good place to expand the GPR work and see if more features in the form of deposits of fire cracked rock or pit features might be visible in the data.

Site Formation Processes

While it was not initially a part of the hypothesis, the insight that the remote sensing provided about the environmental processes affecting the sites turned out to be an unplanned bonus.

The erosion that Matzhiwin Creek has caused to EfOx-70 and EfOx-71 was clear simply from comparing the changes in EfOx-71 between the 2017 and 2019 visits to the site. A boiling pit photographed and recorded in the creek bank in 2017, had disappeared by 2019. But the comparison of the modern satellite images to the historic air photos made clear how far the creek has moved in about 65 years. In that time, Matzhiwin Creek has moved over 40 m to the east, eating away at the west bank of EfOx-71 as it moved, likely removing tons of archaeological remnants in the process.

The formation of gypsum at EfOx-70 and its effects on the GPR results are also interesting in both an anthropological sense and an environmental sense. In this area, the ability of the sand to hold on to water a meter or more above the creek will affect the vegetation able to grow above it while it also reflects the use of the location as an initial butchering site. This theory would be interesting to test at other initial butchering sites near water to see if similar GPR and XRD results occur.

Although the concretion layer at EfOx-77 in the GPR profiles may never have been on the surface and therefore not directly helpful to the artifacts found above it, it does represent a period of dune stability that the archaeological remains are a part of. This tells us that the physical environment of EfOx-77 has not changed significantly since the deposition of the artifacts aside from 30+ cm of sand deposition.

Landscape archaeology of the Mattheis Ranch

The results of the remote sensing analysis on the Mattheis Ranch offers suggestions for future work on the ranch by providing targets of future excavations along the Red Deer River Valley and expanded drone surveys targets along Matzhiwin Creek.

The location of the sites on the edge of the Red Deer River upper valley margin is important; it suggests summer camps that allow visibility far down the river valley in both directions. Aside from the obvious practical ability to see people and bison herds for miles, the view is stunning and had to have had an effect on people then, that is similar to those living there now. The possible ring and drying area at EfOx-80 hint at some of the activities occurring against this backdrop.

At the Matzhiwin Creek sites, EfOx-70, EfOx-71, EfOx-72, EfOx-73, EfOx-74, EfOx-75, EfOx-77 and EfOx-83 all cluster around a bowl shape formed by the creek valley that excavations have shown contains a significantly sized bison kill complex. EfOx-8 is currently on the east side of highway 36, but if the theory of the use of the area as a bison jump holds out, this site may prove to be part of the complex. Thanks to the examination of the aerial data available for this area, testable theories have emerged to determine whether people are using a jump or pound method of bison procurement.

Geophysical Research Design

Aerial remote sensing data is frequently used as part of planning a new archaeological project whether there are known sites in the area or not. Its ability to show the landscape and suggest likely places favourable to longer term habitation or travel routes make it an obvious go-to at the earliest parts of project planning. Near Surface Geophysics (NSG) is not so easy to reflexively include.

At a Field Methods Symposium organized by the Association of Consulting Archaeologists and Alberta Culture and Tourism in March of 2015, Dr. Terrance Gibson outlined some of the conditions under which Near Surface Geophysics should, and should not, be considered.

> "NSG applications are best applied to areas known or strongly suspected to contain cultural remains that can be detected by them." (Gibson 2015b: 19)

Near surface geophysics are not a good method for finding previously unknown sites. Some knowledge of the local surficial geology must be in hand before the survey takes place to ensure that the signals of any cultural materials present will not be drowned out by the background environment. But where a site is known to be present and the types of artifacts and features it contains can be surmised, a research plan employing the appropriate detection methodology can be designed. This may include the magnetometry and GPR methods employed in this research, but it may also include methods like magnetic susceptibility, electromagnetic or conductivity/resistivity surveys.

> “[Near Surface Geophysics] applications are especially useful for assessing sites that have been tested, but their recoveries are either ambiguous or so complex that further excavation is difficult to undertake without much more invasive and time-consuming testing.” (Gibson 2015b: 19)

Geophysics can not, and should not be done at every site discovered as part of a Cultural Resource Management process, for example; but if any mitigation work is to be done, appropriate near surface geophysics could be part of a research design that includes testing the results of the NSG survey. The design must have a hypothesis of what is likely to be found from the start so that the appropriate technology can be used and a way to test any features found in the data can be planned.

Good locations would be large pre-contact sites with many activity areas to be mapped and/or tested, thereby extending knowledge of features within the site. Historic structures and sites also make good targets as shown in european sites where an entire Roman town has been mapped via GPR (Trinks et al 2018), but there has also been some success at a Métis wintering site in Saskatchewan (Wadsworth et al. 2021).

Sites where certain below-surface layers such as distinct palaeosol layers are also a good fit for geophysics. GPR results showing compacted layers or magnetometry results showing distinct dipoles can help direct excavations to determine where features can be found within a site.

The very features that make geophysical methods useful to landscape archaeology on the northern plains—its ability to detect soil disturbances, and site- and feature-level patterns—also means there are also definitely circumstances where they are just not going to be appropriate or informative. As the power transmission lines over EfOx-70 and EfOx-71 show, there are places where some methods just will not work. Materials like bentonite clay, formed partially from volcanic ash, or salt water that are both electrically conductive will not work with GPR if they are too close to the surface as they conduct the radar signal away from the receiver.

> "Geophysical applications should not be undertaken solely to demonstrate cultural remains are not present in an area." (Gibson 2015a: 20)

There are very few instances where any type of geophysics will be measuring the archaeological artifacts directly in pre-contact northern plains camp sites. There are no brick and mortar wall structures and generally artifacts will be too small to be seen. Only certain types of artifacts can be detected directly, so usually the geophysical data is giving results at a feature level instead. For example, individuals tipi ring stones will not be recognizable as artifacts, but a circle of them with a blank area in the middle, as at EfOx-80 will be recognizable as a feature. Debitage and faunal materials such as bones discovered around a magnetic anomaly will not be what created the anomaly, but will be the normal refuse found around a now invisible or buried hearth feature that did create it (Roe at al 2017).

Because artifacts can not generally be identified directly in geophysical surveys, NSG must be part of a strategy that hypothesizes site process that may be environmental or anthropological, and that includes some method of subsurface testing (eg. excavations, test pits, auger testing or bore holes, bank exposures, etc.). Geophysics can not be the only method of demonstrating the presence or absence of cultural materials, though it may be used to search for features that subsurface tests may have missed.

The strength of geophysics lies in expanding knowledge of a known site for the purposes of connecting separated subsurface exposures, and connecting our knowledge of how each space was used. This information may be used to guide further subsurface testing, or to get a clearer picture of how people moved through and used different areas of a site.

In short, given the right conditions and planning, geophysical methods can be valuable tools in expanding our understanding of site use on the northern plains, especially when put into a larger context with aerial data. Aerial data can be, and has been, used to locate previously unknown sites (Parcak 2019) and the two together can be very powerful.

Conclusions

At the beginning of this thesis, four questions were asked:

1) What can the application of remote sensing techniques tell us about the history of archaeological sites in Alberta? What are some of the opportunities and challenges of these methods?
2) Can features such as the cairns and tipi ring rocks be mapped using aerial imagery to make a determination of how people are using sites?

3) Can near surface geophysics in the forms of GPR and magnetometry offer any insight into subsurface anthropogenic features at these transitory sites that were likely chosen with the location of the bison herds foremost in mind?
4) What natural landforms are incorporated and/or exploited by the people using the area and what natural processes have the sites undergone since their creation? What are the conditions that might lead to those places being detectible through remote sensing?

This research was able to offer insight into all these questions and suggest future avenues of inquiry to learn more about the specific sites on the Mattheis Ranch.

The specific challenges of the pre-contact plains sites examined is that they are being used by highly mobile groups of people, and the fact is, any type of remote sensing is only going to be helpful where people have stayed in one place long enough or regularly enough to make a significant impact on the land. On the Alberta plains, that means winter sites are more likely to be detectable by geophysics than shorter-term summer sites, but large scale events like community bison kills could also leave a significant impact.

In areas where that impact has been made, geophysics is a good method for conducting below-surface within-site analysis. Lower resolution aerial data such as air photos and satellite images have long since proven their value for between site analysis, but the arrival of low flying UAV data gives the option of looking within site footprints for specific features like tipi ring rocks and cairns.

In a lot of cases, people would have had to have been using these sites either very intensively over a short period, or repeatedly return for these sites to become visible, persistent places. That said, there are indications that they can offer insights into pre-historic sites, people just need to have been there long enough or often enough to have left some kind of mark of the landscape. The results at EfOx-80 show that there are certainly targets that can be identified for future excavation or testing.

Ultimately, these technologies offer a way to not only visualize how past peoples were using their environment, but the impact that their use had on it over time.
All forms of remote sensing can be used to test hypothesis about archaeological sites but they must be used as part of a larger program that includes ways to test results of the surveys from the moment a project is conceived. The survey methods used will be dictated by the particular limitations of the site and the focus of the hypothesis to be tested.

In the case of smaller features within sites such as cairns or tipi rings, the high resolution of drone data can not be matched. Even with the limitation of overhead barriers such as power lines and trees, in most cases on the plains UAV images can be collected close enough to the ground to be sub-centimetre in resolution if desired. Success in capturing the rocks in the tipi rings at EfOx-80 has led to more research into whether rings can be digitally mapped using drone image classifications. Success in this application could lead to digitally searching large areas for cairns and drive lanes.

Aerial data can be widely applied and with UAV technology dropping in price and increasing in capabilities, there is the opportunity for incredibly precise control over where and how data is collected to test a hypothesis. Geophysical data must be more carefully applied due the physical limitations of the equipment, but where its use is feasible, it has real potential to provide insight into hypothesis testing, guiding excavations, and discovering how different parts of a site might have been used in relation to each other.

Over all, remote sensing was shown to be a collection of useful tools in directing archaeological research and hypothesis testing. Aerial data provides good context for near surface geophysical techniques which in turn offer information at a feature level within sites. While aerial data is often one of the first resources used when planning an archaeological project, near surface geophysics should be included in the planning stages of a project when ways of testing theories based on their results can be incorporated into the research design.

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Appendix 1: Data Collection Settings

GPR Data Collection

Red Deer River Valley Data Collection

EfOx-59 East GPR

Project	2018 Data Collection
Permit	18-034
Date	May 22, 2018
Site	EfOx-59
Grid ID	EfOx-59 East
Grid Size	60 X 60 m
System Set Up	400 3 Wheel Cart
File # Start	162
File # Stop	281
Antenna	400 MHz
T_Rate	100 kHz
Mode	Distance
Samples	512
Format (bits)	16 bits
Range (ns)	50 ns
Dielectric	8.00
Rate	120
Scans/Unit	50
Gain (dB)	0
Gain	Manual
Gain 1 (dB)	-20
Gain 2 (dB)	37
Gain 13 (dB)	47

EfOx-59 West GPR

Project	2018 Data Collection
Permit	18-034
Date	May 23, 2018
Site	EfOx-59
Grid ID	EfOx-59 West
Grid Size	60 X 60 m
System Set Up	400 3 Wheel Cart
File # Start	282
File # Stop	401
Antenna	400 MHz
T_Rate	100 kHz
Mode	Distance
Samples	512
Format (bits)	16 bits
Range (ns)	50 ns
Dielectric	8.00
Rate	120
Scans/Unit	50
Gain (dB)	0
Gain	Manual
Gain 1 (dB)	-20
Gain 2 (dB)	32
Gain 13 (dB)	42

EfOx-80 North GPR

Project	2018 Data Collection
Permit	18-034
Date	May 24, 2018
Site	EfOx-80
Grid ID	EfOx-80 North
Grid Size	30 X 50 m
System Set Up	400 3 Wheel Cart
File # Start	340
File # Stop	401
Antenna	400 MHz
T_Rate	100 kHz
Mode	Distance
Samples	512
Format (bits)	16 bits
Range (ns)	50 ns
Dielectric	8.00
Rate	120
Scans/Unit	50
Gain (dB)	0
Gain	Manual
Gain 1 (dB)	-20
Gain 2 (dB)	37
Gain 13 (dB)	47

Matzhiwin Creek Data Collection

EfOx-77 Area A 2018 GPR

Project	2018 Data Collection
Permit	18-034
Date	May 25, 2018
Site	EfOx-77
Grid ID	EfOx-77 Area A
Grid Size	24 x 32 m
System Set Up	400 3 Wheel Cart
File # Start	001
File # Stop	046
Antenna	400 MHz
T_Rate	100 kHz
Mode	Distance
Samples	512
Format (bits)	16 bits
Range (ns)	50 ns
Dielectric	8.00
Rate	120
Scans/Unit	50
Gain (dB)	0
Gain	Manual
Gain 1 (dB)	-20
Gain 2 (dB)	32
Gain 13 (dB)	42

EfOx-77 Area A Grid 1 GPR

Project	Field School 2019
Permit	19-059
Date	June 3, 2019
Site	EfOx-77
Grid ID	Area A Grid 1
Grid Size	20 X 20 m
System Set Up	400 Survey Wheel
File # Start	019
File # Stop	058
Antenna	400 MHz
T_Rate	100 kHz
Mode	Distance
Samples	512
Format (bits)	16 bits
Range (ns)	50 ns
Dielectric	8.00
Rate	120
Scans/Unit	50
Gain (dB)	0
Gain	Manual
Gain 1 (dB)	-20
Gain 2 (dB)	45
Gain 13 (dB)	49

EfOx-77 Area A Grid 2 GPR

Project	Field School 2019
Permit	19-059
Date	June 7, 2019
Site	EfOx-77
Grid ID	Area A Grid 2
Grid Size	20 X 20 m
System Set Up	400 Survey Wheel
File # Start	059
File # Stop	098
Antenna	400 MHz
T_Rate	100 kHz
Mode	Distance
Samples	512
Format (bits)	16 bits
Range (ns)	50 ns
Dielectric	8.00
Rate	120
Scans/Unit	50
Gain (dB)	0
Gain	Manual
Gain 1 (dB)	-20
Gain 2 (dB)	47
Gain 13 (dB)	54

EfOx-77 Area A Grid 3 GPR

Project	Field School 2019
Permit	19-059
Date	June 7, 2019
Site	EfOx-77
Grid ID	Area A Grid 3
Grid Size	20 X 20 m
System Set Up	400 Survey Wheel
File # Start	099
File # Stop	281
Antenna	400 MHz
T_Rate	100 kHz
Mode	Distance
Samples	512
Format (bits)	16 bits
Range (ns)	50 ns
Dielectric	8.00
Rate	120
Scans/Unit	50
Gain (dB)	0
Gain	Manual
Gain 1 (dB)	-20
Gain 2 (dB)	51
Gain 13 (dB)	51

EfOx-77 Area C 2018 GPR

Project	2018 Data Collection
Permit	18-034
Date	May 25, 2018
Site	EfOx-77
Grid ID	EfOx-77 Area C
Grid Size	15 x 50 m
System Set Up	400 3 Wheel Cart
File # Start	048
File # Stop	071
Antenna	400 MHz
T_Rate	100 kHz
Mode	Distance
Samples	512
Format (bits)	16 bits
Range (ns)	50 ns
Dielectric	8.00
Rate	120
Scans/Unit	50
Gain (dB)	0
Gain	Manual
Gain 1 (dB)	-20
Gain 2 (dB)	32
Gain 13 (dB)	42

EfOx-70 GPR

Project	Field School 2019
Permit	19-059
Date	May 24, 2019
Site	EfOx-70
Grid ID	EfOx-70
Grid Size	2.5 x 10 m
System Set Up	400 Survey Wheel
File # Start	003
File # Stop	007
Antenna	400 MHz
T_Rate	100 kHz
Mode	Distance
Samples	1024
Format (bits)	16 bits
Range (ns)	50 ns
Dielectric	8.00
Rate	64
Scans/Unit	50
Gain (dB)	0
Gain	Manual
Gain 1 (dB)	-20
Gain 2 (dB)	29
Gain 13 (dB)	44

EfOx-71 GPR

Project	Field School 2019
Permit	19-059
Date	May 24, 2019
Site	EfOx-71
Grid ID	EfOx-71
Grid Size	5 x 5 m
System Set Up	400 Survey Wheel
File # Start	009
File # Stop	018
Antenna	400 MHz
T_Rate	100 kHz
Mode	Distance
Samples	1024
Format (bits)	16 bits
Range (ns)	50 ns
Dielectric	8.00
Rate	64
Scans/Unit	50
Gain (dB)	0
Gain	Manual
Gain 1 (dB)	-20
Gain 2 (dB)	29
Gain 13 (dB)	44

Magnetic Gradiometry Data Collection

Red Deer River Valley Data Collection

EfOx-80 North Mag

Project	2018 Data Collection
Permit	18-034
Date	May 24, 2018
Site	EfOx-80
Grid ID	EfOx-80 North
Grid Size	30 X 50 m
Survey	Walk Grad
Positioning System	WGS 84
Cycling	0.5 seconds
AC Filter	60 Hz
File Name	008efoxne
Sensor Distance Apart	63 cm
Sensor Distance From Ground	35 cm

EfOx-80 South Mag

Project	Field School 2017
Permit	17-056
Date	June 8, 2017
Site	EfOx-80
Grid ID	EfOx-80 South
Grid Size	40 x 40 m
Survey	Walk Grad
Positioning System	NAD 83
Cycling	0.5 seconds
AC Filter	60 Hz
File Name	06EfOx81
Sensor Distance Apart	56 cm
Sensor Distance From Ground	5 cm

EfOx-59 East Mag

Project	2018 Data Collection
Permit	18-034
Date	May 24, 2018
Site	EfOx-59
Grid ID	East Mag Grid
Grid Size	30 X 60 m
Survey	Walk Grad
Positioning System	WGS 84
Cycling	0.5 seconds
AC Filter	60 Hz
File Name	07efox59
Sensor Distance Apart	63 cm
Sensor Distance From Ground	35 cm

Matzhiwin Creek Data Collection

EfOx-77 Area A Mag

Project	2018 Data Collection
Permit	18-034
Date	May 25, 2018
Site	EfOx-77
Grid ID	EfOx-77 Area A
Grid Size	24 X 32 m
Survey	Walk Grad
Positioning System	WGS 84
Cycling	0.5 seconds
AC Filter	60 Hz
File Name	05area-a
Sensor Distance Apart	63 cm
Sensor Distance From Ground	35 cm

EfOx-77 Area A Grid 1 Mag

Project	Field School 2019
Permit	19-059
Date	June 3, 2019
Site	EfOx-77
Grid ID	Area A Grid 1
Grid Size	20 X 20 m
Survey	Walk Grad
Positioning System	NAD 83
Cycling	0.2 seconds
AC Filter	60 Hz
File Name	15 EfOx-77
Sensor Distance Apart	59 cm
Sensor Distance From Ground	5 cm

EfOx-77 Area A Grid 2 Mag

Project	Field School 2019
Permit	19-059
Date	June 7, 2019
Site	EfOx-77
Grid ID	Area A Grid 2
Grid Size	20 X 20 m
Survey	Walk Grad
Positioning System	WGS 84
Cycling	0.2 seconds
AC Filter	60 Hz
File Name	16 EfOx-77
Sensor Distance Apart	58 cm
Sensor Distance From Ground	10 cm

EfOx-77 Area A Grid 3 Mag

Project	Field School 2019
Permit	19-059
Date	June 7, 2019
Site	EfOx-77
Grid ID	Area A Grid 3
Grid Size	20 X 20 m
Survey	Walk Grad
Positioning System	WGS 84
Cycling	0.2 seconds
AC Filter	60 Hz
File Name	17 EfOx-77
Sensor Distance Apart	58 cm
Sensor Distance From Ground	10 cm

Transmission Line Mag

Project	2018 Data Collection
Permit	18-034
Date	May 25, 2018
Site	North of EfOx-77
Grid ID	Line Test
Grid Size	1 X 560 m
Survey	Walk Grad
Positioning System	WGS 84
Cycling	0.5 seconds
AC Filter	60 Hz
File Name	10liness
Sensor Distance Apart	63 cm
Sensor Distance From Ground	35 cm