Multi-Method Geoarchaeological Analysis of the Prehistoric White Creek Village Site

by

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This thesis represents a pilot program to incorporate minimally-invasive geochemical methods to research prehistoric village sites in the Frank Church-River of No Return Wilderness, Idaho. The goal of this research is to characterize prehistoric activity zones at the White Creek site (10-CR-576) through chemical analysis of soil samples collected in 2016. Soil samples were analyzed for magnetic susceptibility and elemental concentration. To measure elemental concentration, samples were analyzed with a handheld portable X-Ray Fluorescence (HHpXRF) instrument. Additionally, soil samples were prepared with a chemical soil extraction method and analyzed using ICP-MS, but the results of this analysis were unavailable at the time this thesis was completed and defended.

Spatial variations of elemental concentrations were compared to one another and to magnetic susceptibility data with correlation and Student T-test calculations. This research found that concentrations of P, Ba, Ca, and Sr covary across the samples. Variation in P correlated to magnetic susceptibility of the soils. These four elements were depleted in ash-enriched samples from the site. Ca was enriched within samples adjacent to those enriched in ash. Combining this data suggests that fires for animal processing/cooking were used in this location by prehistoric occupants. This supports the conclusions of other researchers that characterize the White Creek site as a Late Prehistoric campsite. Variation in other elements, particularly K, may be explained by natural geologic processes rather than anthropogenic activity.

This study concludes that prehistoric anthropogenic signatures in the soil at the White Creek site are still preserved despite thousands of years of erosion and historic/modern use of the terrace by campers. The variation is not caused by recent natural and/or anthropogenic processes. The results of this study lead the researcher to recommend incorporating geochemical methods in more archaeological research projects in the area.

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Preface

I would like to thank Dr. Bryan Hanks and Dr. Tim Canaday for providing the opportunity for me to volunteer with the Middle Fork Geophysics Research Project. My experiences at the Big Creek and Confluence village sites during the 2018 field season inspired me to pursue the research developed in this BPhil Thesis as well as work towards a career in North American archaeology. My ability to travel to the sites would not have been possible without the assistance of the Center for Comparative Archaeology of the University of Pittsburgh Anthropology Department and the Salmon-Challis National Forest Service.

This thesis relies heavily on data collected by the MFGRP and decades of research compiled by the FC-RONRW NFS archaeologists. I would again like to thank Dr. Bryan Hanks and Dr. Tim Canaday for providing access to this data. The use of the documentation and soils detailed within this thesis was permitted through an agreement and ARPA/Antiquities Permit with the U.S. Department of Agriculture, Forest Service, held by Dr. Bryan K. Hanks.

Finally, I would like to thank Dr. Bryan Hanks, Dr. Marc Bermann, and Dr. Tim Canaday for their archaeological geophysics expertise as members of the MFGRP. I would like to thank Dr. Bryan Hanks and Dr. Rosemary Capo for training me in the lab methods used in this thesis and helping me to develop this research. Funding for some elements of this research was provided by a University of Pittsburgh Dietrich School of Arts and Sciences Social Science Research Initiative Grant.

1. Introduction

The Frank Church - River of No Return Wilderness (FC-RONRW) in Central Idaho is one of the largest wildernesses in the continental United States and there is virtually no infringement from modern development **(Fig. 1)**. Cutting through this wilderness is the Salmon River and its major tributaries. The terrain is rugged and significantly limits accessibility to the over 2,365,000 acres of wilderness. Visitors must travel by foot, pack animal, river raft, and/or fixed wing aircraft **(Canaday and Hanks 2014).** Access to a large area of the Frank Church Wilderness is facilitated by rafting down the two major rivers. One of the major tributaries of the Salmon River, the Middle Fork, is especially popular for whitewater rafting and each year approximately 10,000 people float the 104 miles.

Numerous prehistoric and historic cultural resources have been identified within the Frank Church Wilderness. These sites represent continuous occupation of the region since the beginning of the Holocene (10,000-12,000 B.P.) **(SCNF 2016: 11, Canaday and Hanks 2014, Knudson et al 1982: 75, McGuire and Matz 1994: 27)**. As of 2012, U.S. National Forest Service archaeologists from the six districts included in the Frank Church Wilderness have identified 584 prehistoric sites, 547 historic sites, and 134 mixed occupation sites **(SCNF 2016: 10)**.

The FC-RONRW is managed by four National Forests: The Bitterroot, Nez Perce, Payette, and Salmon-Challis National Forests (see **Fig. 1**) **(Canaday 2012: 4)**. Managing the cultural resources in such a vast region requires a significant collaborative effort. The Wilderness is federally protected with provisions requiring the inventory and management of cultural resources **(Canaday 2012: 3)**. Due to the narrow valley and steep sides of the Middle Fork, camping along the river by the public often occurs on or adjacent to prehistoric cultural sites, particularly pit house village locations. This has in some cases accelerated erosion on the terraces. To combat these processes, the NFS sometimes restricts access to specific terraces and provides informational pamphlets to commercial river rafting companies about the cultural resources along the river.

This thesis investigates the efficacy of geophysical and geochemical analyses at White Creek, a prehistoric village site located on the banks of the Middle Fork Salmon River in the heart of the FC-RONRW. In the following pages I discuss the pilot research design I developed to study anthropogenic elemental signatures in soil samples from the site. In this thesis, I present the spatial variation of such elemental signatures and provide interpretations for the data.

1.1. Archaeology in the Frank Church Wilderness

The difficult logistics of working in the Frank Church Wilderness has limited both the identification and study of cultural resources. This is particularly the case for prehistoric sites that lack obvious surface features and as a result many more sites likely remain unrecorded. The prehistoric archaeology of the Middle Fork Salmon River is of special concern due to strong public interest in accessing this area during the summer season for white water rafting.

Systematic archaeological research along the Middle Fork Salmon River began in 1958 when Earl Swanson and John Rice of the Idaho State College Museum conducted a reconnaissance from Indian Creek to the confluence of the Salmon River (about 100 miles) **(Swanson 1958: 1)**. Swanson **(1958)** identified a dense concentration of prehistoric sites in the stretch between Loon Creek and Camas Creek. This density was corroborated and quantified in a later US Forest Service -led reconnaissance as 2.3 sites per mile near Loon Creek and 2.6 sites per mile near Camas Creek, compared to an average of 1.7 sites per mile along the entire 100-mile stretch **(Kulesza 1983: 27).** The greatest site density occurs between Pungo Creek and Big Creek where the overall density of sites with house pit depressions is 0.9 sites per mile. In total, 160 to 180 prehistoric sites along the Middle Fork have been identified (see **Fig. 2**) **(Kulesza 1983: 27).** Because of the logistical challenges of field research, limited excavations along the river corridor have been focused primarily at Big Creek **(Leonhardy and Thomas 1983)**, Dagger Falls **(Holmer 1989),** Cameron Creek, Survey Creek, White Creek (all three were test excavated by **Trowbridge 1989**), and Pungo Creek **(McGuire and Matz 2001)** sites. Until 2014, surface surveys were the main management strategy for prehistoric resources in the Middle Fork Valley **(Canaday 2012: 127-137, SCNF 2016: 23-32)**.

As of 2004, the NFS has followed a management plan developed by a long-term Land Management Direction and a Programmatic Agreement (PA) to identify, evaluate, and then preserve, enhance, and/or investigate cultural resources within the FC-RONRW **(SCNF 2016: 23-32).** Completion of a Historic Preservation Plan **(SCNF 2016)** now provides guidance for management of cultural resources in the FC-RONRW. Preservation efforts in the Middle Fork especially focus on "resolving problems where there are known or potential impacts and conflicts to cultural resources," particularly prehistoric sites affected by campers **(SCNF 2016: 27).** Scientific investigations of prehistoric sites by the NFS are guided by two strategies:

> *1. Focused subsurface testing of key sites as mitigation of adverse effects following consultation with the Idaho State Historic Preservation Office (SHPO) and affected federally recognized Tribes.*

2. Focused subsurface testing of key sites as necessary to address research questions following consultation with SHPO and affected federally recognized Tribes.

(SCNF 2016: 30)

Prehistoric cultural resource management strategies in the Middle Fork prioritize identification and mitigation. Section 12 of the Standards and Guidelines portion of the 2016 Historic Preservation Plan states:

"Use non-destructive geophysical techniques such as ground penetrating radar, magnetometry, electrical resistivity, soil chemistry, etc., to detect and map subsurface features. Subsequent to non-ground disturbing geophysical fieldwork, consider conducting focused subsurface testing to confirm the geophysical results, determine the extent of damage and whether intact cultural deposits remain"

(SCNF 2016: 34).

The National Forests work closely with Native American tribes when developing management strategies. In recent years, this collaborative effort resulted in direction to investigate sites using minimally invasive research strategies before more invasive methods are contemplated. No excavations or test-pit investigations at Native American sites in the Frank-Church Wilderness have occurred since 2002 **(Canaday 2012: 127-137, SCNF 2016).** The summer of 2014 marked the first season of the Middle Fork Geophysics Research Project, a collaborative effort between the Salmon-Challis National Forest and the University of Pittsburgh, to implement this guideline.

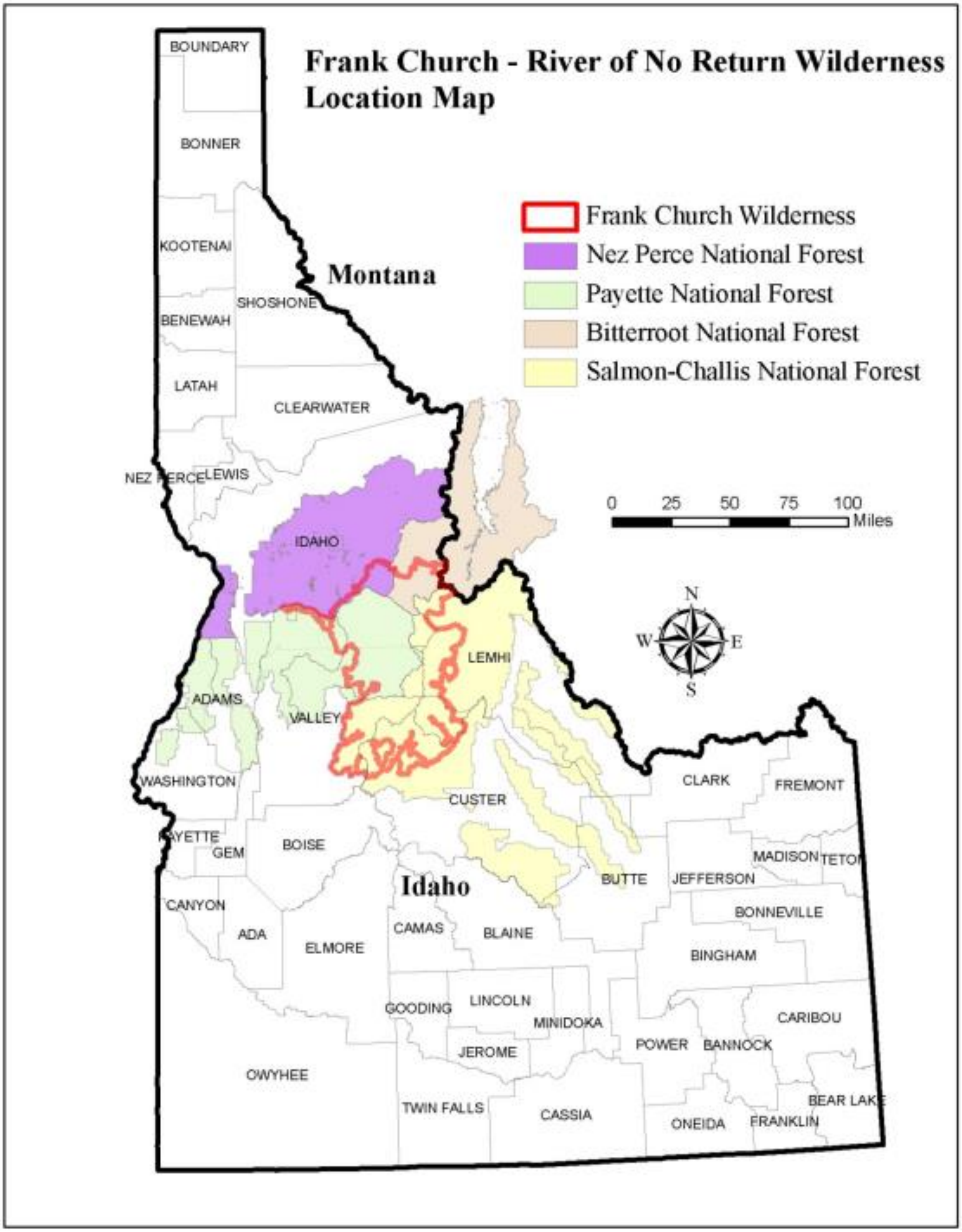


Figure 1. *Map of Frank Church River of No Return Wilderness with associated National Forests (after SCNF 2016: 2).*

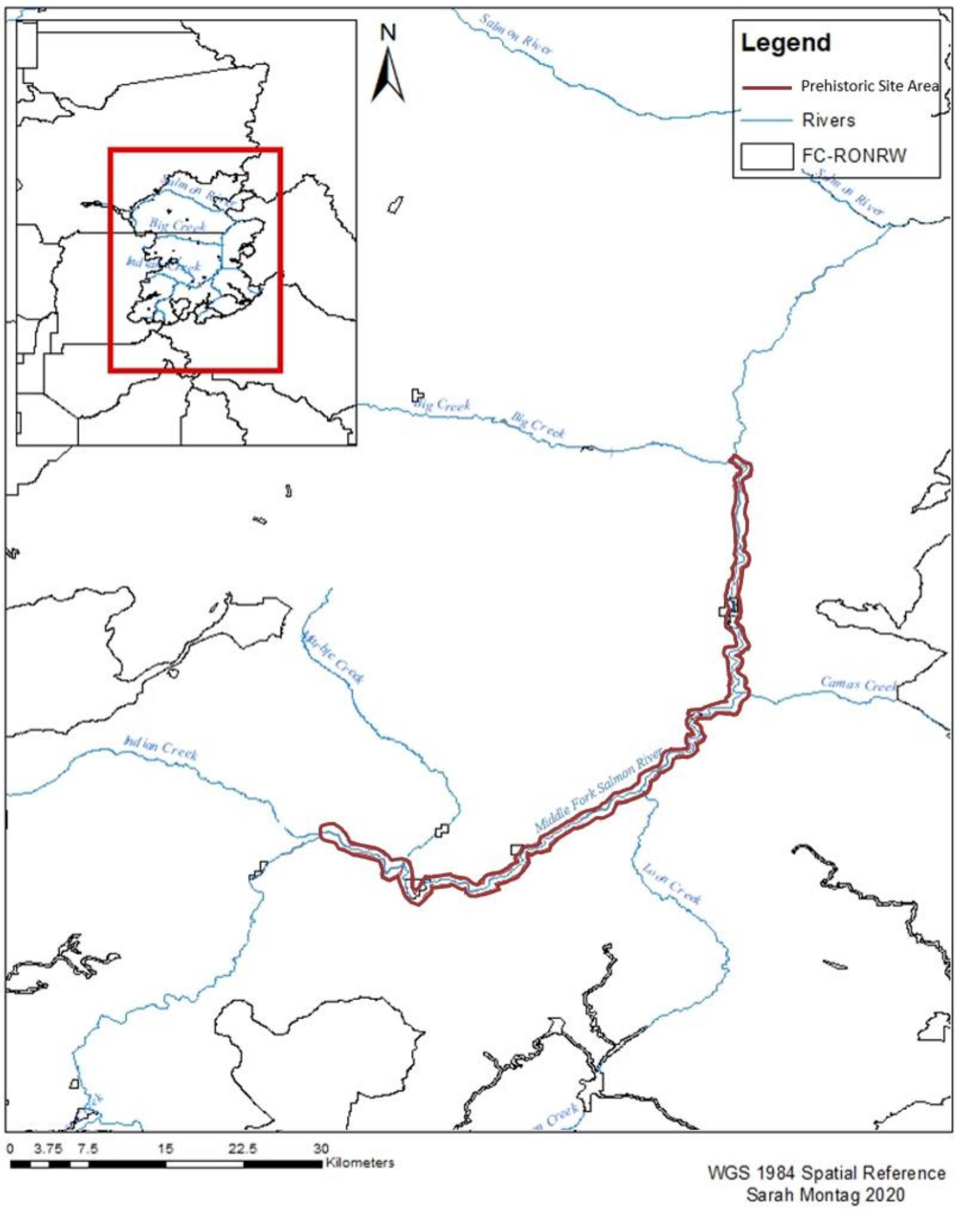


Figure 2. *Map detailing density of prehistoric archaeological sites along the Middle Fork and Indian Creek and Big Creek tributaries. The length of the Middle Fork Salmon River outlined in red has the densest prehistoric habitation (0.9 sites/mile) (Kulesza 1983:29) (after SCNF 2016:5).*

2. The Middle Fork Geophysics Research Project (MFGRP)

In the summer of 2014, a new project in the Middle Fork Salmon River valley was initiated that continued seasonally through the summer of 2018. This pilot project utilized geophysical and geochemical survey methods at known prehistoric sites along the Middle Fork of the Salmon River to assess the potential for using archaeological geophysics to spatially characterize prehistoric pit house villages and to inform future management of these sites by the US Forest Service. Many of the prehistoric village sites along the Middle Fork are at risk of impact due to campsites that are assigned to seasonal rafting parties. Such camps promote compaction of surface soils and potentially harm localized vegetation, which stimulate both wind and water soil erosion of the sites. The pilot program was designed to study such sites in detail using minimally invasive methods to assist in the management of these at-risk prehistoric village sites.

The Middle Fork Geophysics Research Project (MFGRP) is a collaboration between the Salmon-Challis National Forest (led by Dr. Tim Canaday) and the University of Pittsburgh Department of Anthropology (led by Dr. Bryan Hanks). Over the five seasons of field work connected with the MFGRP, team members have surveyed 12 sites along the Middle Fork that included: Indian Creek (2014), Pungo Creek (2014), Lower Jackass (2014, 2015, 2016, 2017), Marble Creek (2014, 2015), Hospital Bar (2015, 2016, 2017), Rock Island (2015), White Creek (2015, 2016, 2017), Grassy 2 (2016), Woolard (2017) and Stoddard Creek Camp (2017). As part of this project, the author was a team member during the 2018 season and assisted with geophysical and geochemical surveys at the Confluence and Big Creek village sites.

2.1. Geophysical Survey Methods

A combination of archaeological geophysics instruments was utilized by the MFGRP team **(Fig. 3)**. During every field season, site-scale magnetometry surveys were conducted with a Bartington Grad601 fluxgate gradiometer and this served as the primary form of geophysics data collection at each site. This instrument can be used to detect subtle variations in the Earth's magnetic field due to either near-surface geology and/or anthropogenic activity.

This survey method rapidly collects data over hundreds of square meters in a matter of hours, allowing archaeologists to survey the total extent of large sites **(Kvamme 2006: 7).** By comparing gradiometer data to site reports and topography, anomalies likely associated with prehistoric and historic activity can be identified. These anomalies often include areas that from the surface would not indicate the presence of cultural activity, such as the locations of possible subsurface prehistoric hearths or small storage pits **(Kvamme 2006)**. The value of magnetometry surveys at Middle Fork sites was recognized after the first season (2014) and this method was then utilized at every site for the duration of the project.

Additional geophysical survey methods used at prehistoric sites over the course of the MFGRP include earth resistance (2016, 2018), magnetic susceptibility (2016, 2017, 2018), and electrical conductivity (2017, 2018). These methods were always used in conjunction with magnetometry surveys. Earth resistance soil data was collected with a dual-probe GeoScan RM85 Resistance Meter to depths of approximately 0.5 m below the surface. Extremely dry soil conditions hindered the instrument's ability to collect data during the 2018 field season. Magnetic susceptibility of soil was analyzed in the field utilizing either a SatisGeo KM-7 Field Susceptibility Meter (Kappameter) or a Bartington MS2 Magnetic Susceptibility Meter with an attached MS2D Surface Scanning Probe. Using the Bartington configuration, magnetic susceptibility data was collected at a maximum depth of 6 cm below the surface.

During the last two field seasons (2017, 2018), University of Pittsburgh archaeologists incorporated electrical conductivity and deeper in-phase magnetic susceptibility surveys in the fieldwork. The instrument used for this was a GF Industries CMD Mini-Explorer, which represents a low frequency electromagnetic (EM) method. This instrument simultaneously records apparent electrical conductivity, measured in millisiemens per meter (mS/m) and magnetic susceptibility measurements at depths of 0.5 m, 1.0 m, and 1.8 m (high setting) or depths of 0.25 m, 0.5 m, and 0.9 m (low setting). Both electromagnetic survey methods are beneficial for detecting changes in soils relating to archaeological features (e.g. pits, ditches, compacted soil, etc.) Magnetic susceptibility may be used to approximate the general intensity of anthropogenic activity across a site and is especially adept for identifying enriched soils with magnetic properties. Collectively, these geophysical survey methods were useful for identifying site spatial extent and features but were less effective in characterizing site-specific activities or occupation intensity in detail.

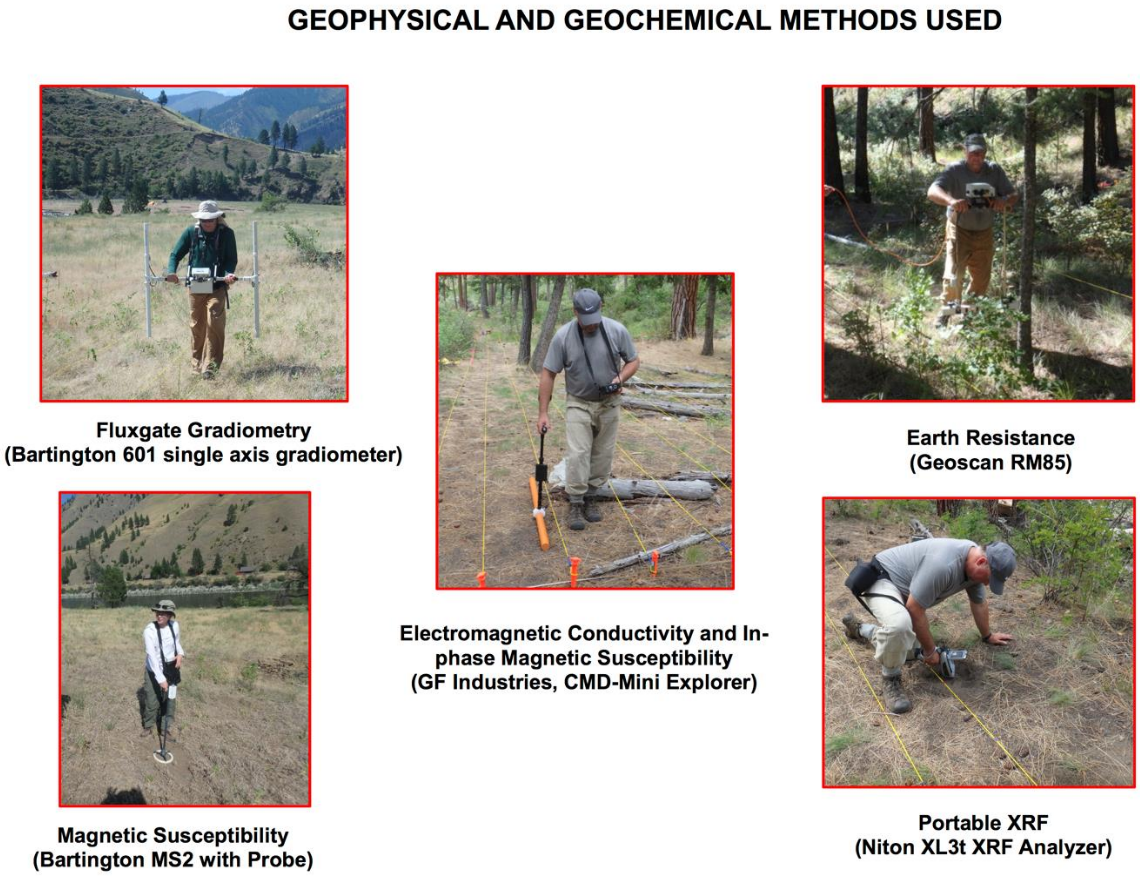


Figure 3. *Geophysical methods used by the MFGRP team (after Canaday et al. 2019).*

2.2. Handheld Portable X-Ray Fluorescence (HHpXRF)

Since the first field season, the archaeologists recognized that incorporating geochemical surveys and analyses in the project could potentially provide more detail on the types of activities and the general occupation intensity that occurred at these prehistoric sites **(Canaday and Hanks 2014).** In 2015, soil samples were collected utilizing a small t-handled soil probe (5/8-inch diameter) from five archaeological sites along the Middle Fork River **(Table 1).** Samples were collected systematically, utilizing grid points set out for geophysical survey, every 10 m to 20m along a single transect line across the sites.

Table 1. *List of archaeological sites and total number of soil samples collected during 2015 season (after Doonan and Hanks 2016, 3).*

Site Name	No of Samples
Hospital Bar	20
White Creek	11
Lower Jackass	23
Marble (kitchen area)	12
Marble (main terrace)	26
Rock Island (terrace 1)	7
Rock Island (terrace 2)	8
Rock Island (terrace 3)	6
Rock Island (terrace 4)	12

These samples were then analyzed ex-situ in Pittsburgh by Dr. Roger Doonan of the University of Sheffield using a Niton XLT3 Handheld Portable X-Ray Fluorescence (HHpXRF) analyzer:

> *HHpXRF analyses were undertaken ex-situ on approximately 25g samples contained within a standard sampling vessel with proline analysis window. Determinations were made using a Niton XLT3 instrument that is equipped with a 50kV X-ray tube, and an Ag anode with a silicon positive intrinsic negative (Si PiN) detector. The area excited is 8mm in diameter giving an analytical area of 50mm^2. The analytical mode chosen was the standard "mining" mode using the main, low, high and light filters in conjunction with a helium purge so as to facilitate light element detection (especially P). Analysis time was adjusted to 135 seconds and determined the following elements (Ba, Nb, Zr, Sr, Rb, Bi, As, Pb, Zn, Cu, Fe, Mn, Cr, V, Ti, Ca, K, Al, P, Si, Cl, Mg, S)*
>
> **(Doonan and Hanks 2016: 3)**.

Following the promising results from 2015 (see pp. 28-9), additional soil samples utilizing a t-handled soil probe were collected in 2016 at the Lower Jackass, White Creek, Hospital Bar, and Grassy 2 sites. Samples were collected at a higher density in certain areas of the sites utilizing 10 m^2 survey blocks with samples taken every 2 m at Lower Jackass and White Creek. Transects with samples taken at multiple depths using a 5/8" t-handled probe were collected at Hospital Bar and Marble Creek. The soil samples collected during the 2016 season are listed in **Table 2** below.

Table 2. *List of archaeological sites and total number of soil samples collected during 2016 season (from T. Canaday's MFGRP 2016 field season notes, (Canaday 2016).*

Site Name	No of Samples
Lower Jackass (locus A)	36
Lower Jackass (locus B)	36
Lower Jackass (locus C)	36
White Creek	52
Hospital Bar (anomaly 1)	36
Hospital Bar (anomaly 2)	26
Hospital Bar (anomaly 3)	9
Grassy 2 (locus A)	12
Grassy 2 (locus B)	6

2.3. Social Science Research Initiative: Development of Interdisciplinary Geophysical and Geochemical Methods of Prehistoric Landscapes

In 2018, Dr. Bryan Hanks and Dr. Rosemary Capo from the University of Pittsburgh received a joint grant to seed fund a new program of interdisciplinary research between the departments of Anthropology and Geology and Environmental Science. This research was designed to integrate archaeological geophysics survey and more detailed geochemical research utilizing HHpXRF and lab-based soil extraction geochemistry. The objectives of this research focused on the following: (i) to further test the suitability of geophysical survey on early pit-house villages within the region; (ii) to provide settlement patterning data, through geophysical survey and geochemical characterization, that may aid in generating a better understanding of prehistoric social organization through demography (number of houses, sizes of houses), activities within the sites, and the spatial orientation of village sites (nature of distribution of pit-houses, number and size of storage pits and hearths, etc.); and (iii) develop a suitable multi-method field and laboratory approach that will aid in the future cultural preservation of these important sites **(Hanks and Capo 2017).**

As part of this new program of study, the soil samples collected during the 2016 field season were brought back to the University of Pittsburgh for analysis. Dr. Bryan Hanks analyzed the soils in 2018 using a new Thermo Fisher Niton XLT3 GOLDD+ HHpXRF purchased by the University of Pittsburgh. This instrument analyzes up to 30 elements using its Geometrically Optimized Large Area Drift Detector (GOLDD). It is equipped with a 50 kV and 200 µA X-ray tube with an Ag anode. Thermo Fisher Scientific reports that GOLDD technology "measures up to 10-times faster than conventional Si-PIN detectors and up to 3-times more precise than conventional smaller silicon drift detectors (SDD)" **(Niton, produce description website)**. Soil samples were analyzed utilizing both "Precious Metals Bulk Modes": "soils" and "mining" modes. With "soils" mode, samples were analyzed with three subsequent filters: "Low" (60 seconds), "High" (60 seconds) and "Main" (60 seconds), for a total integration time of 180 seconds. With "mining" mode, samples were analyzed with "Low" (10 seconds), "Main" (10 seconds), "High" (10 seconds), and "Light" (60 seconds) filters selected for a total integration time of 90 seconds. Samples were analyzed with the "Light" filter for an extended time to reduce the error range reported for light elements, including phosphorus.

During the 2017 and 2018 field seasons, University of Pittsburgh archaeologists used a Thermo Fisher Niton XLT3 GOLDD+ HHpXRF to sample soil chemistry in situ (surface soils). No soil probes were taken or soil samples removed from the field during these seasons. As a research assistant for this project, the author analyzed the White Creek samples again on a recalibrated Niton XLT3 HHpXRF using the same settings as outlined above. The MFGRP also included in its budget funding to perform soil extractions and elemental analyses with inductively coupled plasma spectroscopy (ICP-S) on soil samples from one site. Such analysis represents the most detailed archaeological geochemistry research attempted to date in the Middle Fork of the Salmon River Valley.

2.4. BPhil Thesis Research

A group of 36 soil samples from a 10 m^2 block at the White Creek site was determined to be the best candidate for the soil extraction geochemistry pilot research. Because of the author's previous experience with the MFGRP, background in anthropology and geology, and personal interest in geoarchaeology, Dr. Hanks and I recognized that the geochemistry at the White Creek site represented a unique opportunity for me to research and write a B. Phil thesis. It was anticipated that this would contribute to a better understanding of the archaeology along the Middle Fork and provide an important opportunity to further test the efficacy of geophysical and geochemical analyses at the White Creek site.

Multi-method geochemical analyses on soils from the prehistoric White Creek pit house village site was completed with two goals in mind: i) Identify and qualify specific activity zones based on spatial variability of elements in anthropogenic soils and ii) assess the accuracy of HHpXRF analysis on Middle Fork anthropogenic soils by comparing the results of two geochemistry analysis methods. To achieve these goals, I developed the following research questions:

Research Question 1:
How do concentrations of elements potentially associated with prehistoric anthropogenic activity (namely, Ba, Ca, Mg, Mn, P, K, Sr, and Zn) spatially vary across the 10 m^2 White Creek survey block?

Research Question 2:
Can variability in elemental concentrations be associated with region and period specific anthropogenic activity? Can such variability confidently be associated with prehistoric activity or is it a product of natural geology and soil conditions and/or a product of modern camping activities?

Research Question 3:
Can HHpXRF and soil extraction methods produce comparative results?

Before discussing the methods and results of this research, it is necessary to provide an overview of the natural and cultural environment of the Middle Fork. Because of the nature of this research, the archaeology and geology of the region are discussed in more detail. The results of past archaeological research at the White Creek site are summarized as well.

3. Prehistoric and Historic Occupation of the Middle Fork

Evidence of human occupation in the Middle Fork region spans from the Archaic Period (12,000-10,000 B.P.) to the modern Historic Period **(Pavesic 1978, Knudson et al 1982, SCNF 2016: 11)**. Historic occupants of the Middle Fork Valley were a subgroup of the Northern Shoshoni referred to as the Tukudeka or "The Sheepeaters" **(Pavesic 1978: 3-4, Reddy 1996)**. Analysis of the culture of prehistoric occupants of the Middle Fork is based on local archaeological sites and comparisons with regional prehistoric culture phases.

Cultural practices in the Middle Fork developed at a convergent boundary of distinct cultural zones over thousands of years. North of the Middle Fork is the Plateau culture area and to the south is the Great Basin culture area **(Pavesic 1978)**. The Plains culture area lies to the east of the study area and overlaps in part with the Northeastern Great Basin culture area identified by Butler **(1968)**. Through morphological interpretation of projectile points in the Middle Fork Valley, archaeologists have suggested that the valley's inhabitants maintained "cultural or technological traditional ties to both or either the Columbia Plateau and the northern Great Basin, and perhaps even the Plains" **(Knudson 1982:**

133). The Middle Fork represents a unique cultural zone that requires more archaeological research to fully understand the prehistoric cultural phases identified in the region.

Ethnographic information on the historic occupants of the Middle Fork Valley is limited. Sven Liljeblad **(1957)** and Julian Steward produced much of the ethnographic literature on local populations associated with the Middle Fork. Others, including Robert Lowie, documented the cultures of Central Idaho Native populations but did not distinguish Tukudeka from Lemhi Valley Shoshoni groups **(Pavesic 1978: 5, Knudson et al. 1982: 78)**. This is likely because, "Tukudeka is a cultural-ecological designation, not a political one" **(Pavesic 1978: 4)**. The Tukudeka designation is derived from the Shoshoni and Bannock word *tuku* meaning "flesh" or "meat," and because Northern Shoshoni populations relied predominately on mountain sheep for their meat, the name Tukudeka translates to "mountain sheep eaters" **(Liljeblad 1957: 55)**.

The Tukudeka followed an economic system based on seasonal utilization of available resources within the Valley and surrounding uplands **(Pavesic 1978: 4)**. During the fall and spring, small groups camped in Columbian Plateau-type pit houses along the Middle Fork and its major tributaries in locations best suited to exploit seasonal salmon resources **(Pavesic 1978, Knudson et al. 1982: 31, SCNF 2016: 9)**. Also, in the fall, local groups likely gathered pine nuts in the upper elevations of the valley **(Knudson et al. 1982: 69)**. Tukudeka groups hunted native big game in the winter, which was mostly composed of mountain sheep, but other ungulates were also used **(Knudson et al. 1982: 26, SCNF 2016: 8)**.

In the northern stretch of the Middle Fork (downstream from approximately Big Creek to the confluence of the Main Salmon River), ethnographic reports document the historic occupation of Nez Perce groups **(Knudson et al. 1982: 79, SCNF 2016: 12)**. Trade relationships between the Shoshoni and Nez Perce and the proximal campsites of the two cultures further supports the hypothesis that the Middle Fork Valley was the site of cultural interaction between Basin and Plateau affiliations **(Knudson et al. 1982: 79)**. Shared historic period use of the Valley may have represented the continuation of a long-term trend.

Recognizing cultural phases in the Middle Fork Valley before the historic period is difficult; evidence from the broader region, especially from the Paleoindian and Archaic phases, is approximated for developments within the Valley **(Knudson et al. 1982: 73)**. Clovis points discovered south in the Camas Prairie area and Haskett materials from the nearby Redfish Overhang and Shoup shelters suggest the Middle Fork Valley may have been occupied at the close of the Pleistocene as well **(Pavesic 1978: 8-**

9). Beginning with the Archaic period, Swanson **(1972)** characterized Central Idaho archaeological phases **(Table 3).**

Table 3. *Archaeological Phases of Central Idaho developed by Swanson (Swanson 1972 and Pavesic 1978).*

Archaeological Phases of Central Idaho	
Bitterroot Phase	5,200 - 1,540 B.C.
Beaverhead Phase	1,450 - 950 B.C.
Blue Dome Phase	950 B.C. - A.D. 1250
Lemhi Phase	A.D. 1250 - 1850

In this chronology, Swanson **(1972)** described a continuous occupation of the Middle Fork Valley beginning with Early Holocene big-game hunters through historic inhabitants of the Valley. Swanson relates the groups in the Valley as descendants of the previous phase **(Knudson et al 1982: 77)**. This chronology has been criticized, particularly because these phases are based on cave and rock shelter site archaeology. Linguistic evidence suggests that Shoshoni groups moved into the area much more recently than Swanson suggests **(Reddy 1996)** and that strong cultural influences from beyond the region indicate complex migratory fluctuations in the Valley. Other researchers suggest that the Northern Shoshoni continuously occupied the Valley for the past 3,500-4,000 years **(Holmer 1994, SCNF 2016: 12)**. More archaeological research in the Middle Fork Valley may disprove or lend support to this theory **(Pavesic 1978: 10)**.

The main classes of Middle Fork archaeological features are: i) house-pit depressions (typically found in groups as villages); caves and rock shelters; "tipi ring" depressions associated with occupation after A.D. 1700; rock art sites (mostly ochre pictographs); ceremonial and vision quest sites; and miscellaneous features including lithic scatters, "boulder circles, small rock circles, hunting blinds or pits in talus slopes, undetermined rock structures and a generalized camp designation" **(Pavesic 1978: 19-23, Knudson et al. 1982, SCNF 2016: 10, Kulesza 1983)**. Prehistoric sites typically occur on river and tributary second order (2-8 m above river level) terraces along the Middle Fork **(Knudson et al. 1982: 69)**. Additionally, village sites are sometimes located near "hot springs…and/or possible river fords" **(Knudson et al. 1982: 105, Swanson 1958: 2)**. Pit house village sites typically include 3 to 5 and up to 20 pit house depressions arranged parallel to the river (**Kulesza 1983: 19**). The depressions are shallow, circular or oval, and 10 to 15 feet in diameter. When they were occupied, the pit-houses would have included a pole frame covered with mats or sod **(Fig. 4) (Reddy 1996)**. Today, the remaining depressions are often associated with lithic scatters. Tall grasses and sagebrush often grow within and around the depressions due to anthropogenic soil conditions **(Kulesza 1983: 19-21)**.

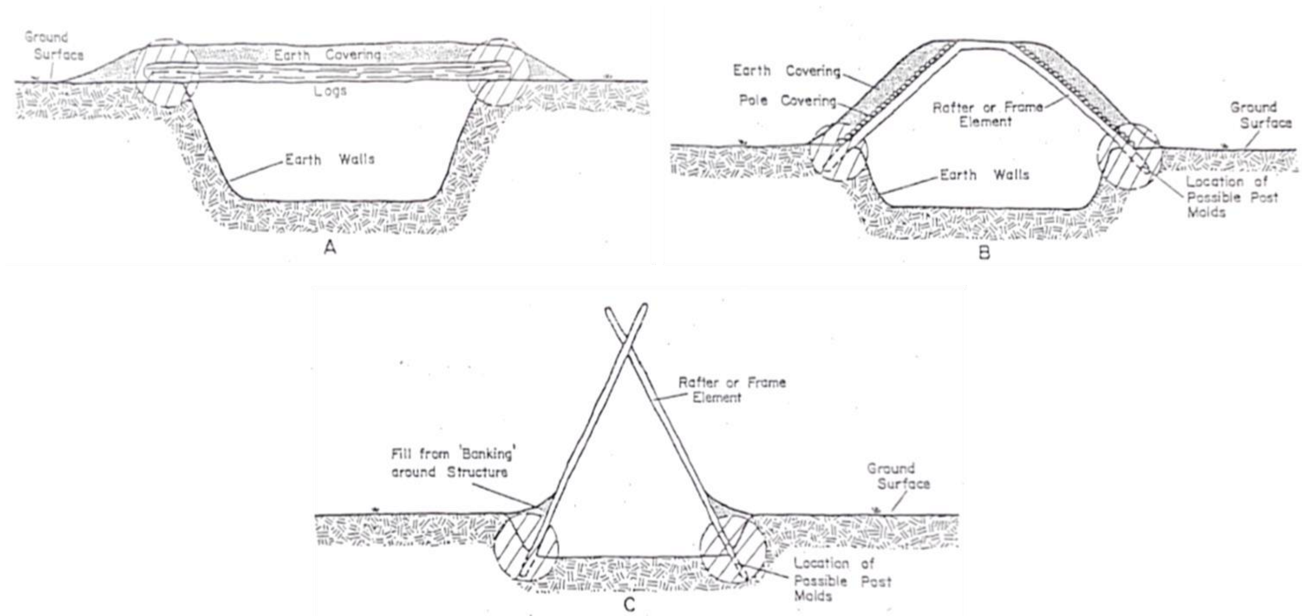


Figure 4. *Possible reconstructions of pit houses (from McGuire and Matz 2001: 67).*

Artifacts identified through pedestrian surveys include projectile points, flaked lithic debitage, other flaked and regular stone tools, ceramics, trade beads, and other historic artifacts **(Knudson et al. 1982: 108-132)**. Collectively, the artifacts suggest human occupation of the Middle Fork dating to “at least 5-6,000 years ago” and continuous occupation from the “early-middle” through the “late-late” prehistoric periods **(Knudson et al. 1982: 133)**. Knudson et al. **(1982: 133)** also note how the raw material and typology of lithic artifacts suggest “cultural or technological traditional ties” to Plateau, Basin, and/or Plains cultural zones.

Studying the archaeology of the Middle Fork may be the key to understanding prehistoric cultural developments of the region. The Middle Fork is a unique cultural zone because of evidence of Plateau, Basin, and Plains influence in prehistory. Preservation along the Middle Fork is remarkable compared to regions outside of the FC-RONRW and may provide enough information to develop an occupation timeline through prehistory. By increasing the intensity of study and adopting novel research methods suited to conditions along the Middle Fork archaeologists will be able to learn more about the archaeology of the region and be better positioned to manage and protect these important cultural resources.

3.1. Archaeological Investigations in the Middle Fork

Because of the logistical challenges of working in the wilderness, archaeological research in the Middle Fork country has been limited. Access options consist of backpacking, utilizing stock/wranglers, rafting, or flying into remote airstrips. The most frequently utilized research strategy in the valley is to perform site reconnaissance and surface surveys on terraces as archaeologists raft down the river. These reconnaissance surveys are documented by Swanson **(1958)**, Pavesic **(1978)**, Dahlstrom **(1972)**, Knudson et al **(1982)**, and Kulesza **(1983)**. Data from these surveys represents strictly surface-level observations as no excavations were conducted. These site assessments helped archaeologists identify which sites would be excavated in the future. Following these earlier surveys, excavations and test-pitting were subsequently conducted at several prehistoric/mixed occupation sites, including Big Creek, Dagger Falls, Cameron Creek, Survey Creek, White Creek, and Pungo Creek.

In 1983, University of Idaho archaeologists excavated the Big Creek site **(McGuire and Matz 2001: 5)**. The archaeologists dug three excavation pits to investigate unusual depressions on the first- and second-order terraces. This research suggested that a very large depression was a house pit feature that included three earth ovens. The unusual size and oval shape of the depressions at this locality are likely the result of post-occupation modifications to better serve the changing needs of Middle Fork Valley occupants **(McGuire and Matz 2001: 6)**. Based on the artifact assemblages, particularly with the aid of diagnostic projectile points, archaeologists dated the Big Creek site to the Late Prehistoric period and noted resemblances to Plateau technology traditions. The presence of fire-cracked rock, charred bone, and hunting tools suggests that the site was occupied by hunter/gatherers in the winter to early spring **(McGuire and Matz 2001: 6)**.

In 1988, Idaho State University archaeologists excavated the Dagger Falls archaeological site to study the prehistoric context before it was disturbed by campground rehabilitation efforts **(Holmer 1989: 3)**. The site is unusual compared to others in the Valley; it occupies two high fluvial/colluvial terraces. Earlier test excavations and the 1988 large scale (143 square meter) excavations produced evidence suggesting the Dagger Falls site was a “limited activity fishing/hunting site occupied within the last 3,000 years” **(Holmer 1989: 3)**. The site did not have evidence of dwelling structures, although talus depressions may have been used as hunting blinds or for storage **(Holmer 1989: 5)**. Thousands of points, stone tools, and utilized flakes, as well as nearly 200 pottery sherds, were recovered from the 1988 excavation **(Holmer 1989: 6)**. Seriation dating of projectile points sets an estimated maximum occupation date of 3,300 years ago. Upper strata contained Desert Side-notched points characteristic of the Late Prehistoric to Historic Period in the Middle Fork Valley **(Holmer 1989: 6-7)**. Projectile point technology and pottery style at the Dagger Falls site suggests the occupants had close ties to the Snake River Basin **(Holmer 1989: 7-8)**.

In the same year, Trowbridge **(1989)** conducted small scale test excavations at seven sites in the Middle Fork Valley, three of which (Cameron Creek, Survey Creek, and White Creek) contained possible house pit depressions. Cameron Creek is a large pit house village site with 22 depressions. Test pits at the site suggest that it was used as a field camp with seasonal hunting occupation **(Trowbridge 1989)**. The Survey Creek site consisted of nine possible house-pit depressions and a lithic scatter, but prehistoric contexts were severely impacted by historic mining and modern camping **(McGuire and Matz 2001: 10)**. With the limited data recovered in the excavations, Trowbridge **(1989)** hypothesized that the site was a field camp and tool production site **(McGuire and Matz 2001: 10)**.

The White Creek site is approximately the same size as the Survey Creek site; it contains nine likely pit house depressions **(Fig. 5)** on a second order terrace **(Trowbridge 1989)**. This site is the focus of my thesis and a complete description is provided in section 5 below.

Archaeologists conducted test excavations at the Pungo Creek mixed-occupation-period archaeological site in 1998. Depressions at the site are associated with prehistoric dwellings. Small scale test excavations performed over the course of a week produced few diagnostic artifacts. Of the recovered lithic debitage artifacts, flake fragments were the largest proportion (73%), suggesting tool manufacturing was a primary activity **(McGuire and Matz 2001: 52)**. The excavations did not produce enough evidence to suggest any more information about subsistence patterns at the Pungo Creek site. Two complete, diagnostic projectile points were recovered at the site: a Basin-type Elko Corner-notched point dated its associated strata to the Middle Prehistoric Period (4500-1500 BP) and a Plains-type Prairie Side-notched point dated its associated strata to the Late Prehistoric Period (1300-300 BP) **(McGuire and Matz 2001: 58)**. The cultural affiliation based on the artifacts is likely an overlap of Plateau, Basin, and Plains influences **(McGuire and Matz 2001: 84)**.

Since the discoveries at Pungo Creek, archaeologists have not excavated in the Middle Fork Valley aside from some shovel probe investigations in 2001 and 2002 in areas affected by wildfires **(Canaday 2012: 137)**. Large-scale excavations along the Middle Fork are logistically challenging due to the rugged terrain. Besides this, the PA established in 2004 stresses identification and damage mitigation of prehistoric sites, not scientific investigation through subsurface excavation **(SCNF 2016)**.

The PA specifically states that the NFS should use minimally invasive research techniques; the MFGRP is a direct response to this initiative.

4. Geology of Central Idaho and the Middle Fork of the Salmon River

As the Middle Fork flows northeast to its confluence with the Main Salmon River, the valley becomes more canyon-like **(SCNF 2016: 15)**. Both the geology and geomorphology of the canyon are reflective of relatively recent geologic events: Eocene igneous events represent most of the exposed rock units in the area and glacial erosion during the Pleistocene-Holocene boundary shaped the valley and deposited quaternary sediment.

The Casto Quadrangle region experienced powerful volcanism during the deposition of the Challis Volcanic Field. Approximately 8 km to the northwest of the confluence of White Creek and the Middle Fork Salmon River is the Thunder Mountain Caldera and approximately 10 km to the southeast are the Van Horn Peak Cauldron Complex and Twin Peaks Caldera **(Larson and Geist 1995: 99, Moye et al 1988: 90)**. Two distinct hypabyssal dyke swarms are located to the south and west. The Casto Pluton intrusion was triggered by the collapse of the Thunder Mountain and Van Horn Peak cauldron complexes **(Larson and Geist 1995: 909)**. Larson and Geist provide a detailed description of the Casto Pluton geology:

> *"…made up of pink to white epizonal granite that contains sub equal amounts of smoky quartz and orthoclase with less plagioclase. Most of the granites are coarse grained, equigranular, and leucocratic with less than 10% biotite and hornblende, although more mafic and porphyritic rocks occur locally. Most of the pluton contains numerous miarolitic cavities"* **(1995: 909)**.

Today, the Casto Pluton is eroded in areas to expose underlying Precambrian metasedimentary units, Cretaceous Idaho batholith, and other rock associated with the Challis Volcanic Field **(Larson and Geist 1995: 909)**.

Following Eocene emplacement of igneous rock bodies, Pleistocene glaciation processes played a crucial role in eroding and depositing sediment to create the topography of the present Middle Fork River Valley. During the Last Glacial Maximum (21,000 BP), the main river valley was not glaciated, although smaller tributaries at its headwaters were frozen **(SCNF 2016: 22)**. Glacial outwash processes occurring from the Last Glacial Maximum to the Holocene eroded and deposited sediment along the valley's length.

At least eleven distinct terrace heights occur on both sides of the Middle Fork of the Salmon River **(Leonhardy 1983: 7)**. On terraces less than 20 m above the water level, alluvium accumulates as point bars along river bends **(Leonhardy 1983: 9)**. Terrace fill is predominately cobble- to boulder-sized gravel occasionally coated with a layer of aeolian sand **(Leonhardy 1983: 15)**. As the river continuously erodes downward in the narrow valley, the point bars remain in situ as stepped terraces dropping down to a sandy beach at water level. The lowest terrace level in the valley (1 m above water level) represents the most recent depositional cycle; this surface is approximated as no more than 2000 years old **(Leonhardy 1983: 15)**. Above 20 m, terraces do not represent point bars but rather "remnants of aggredational episodes in which the canyon was partially filled" and the water level much higher than at present **(Leonhardy 1983: 9)**. The cyclical deposition and erosion of high terraces was likely related to deglaciation processes **(Leonhardy 1983: 10)**.

5. The White Creek Site (CH-228; 10-CR-576)

The White Creek site **(Fig. 5)** is located on the first terrace above a sandy beach parallel to the Middle Fork of the Salmon River **(Kingsbury and Stoddard 1996: 1)**. On-site sediment deposition and transportation are due to the down-cutting White Creek and Ford Creek adjacent to the terrace **(Kingsbury and Stoddard 1996: 4)**. A site report prepared by Kingsbury and Stoddard in 1996 describes the soil at the site as sandy, with "…an abundance of culturally modified stone tools, fire cracked rock with smaller amounts of organics." The sandy alluvium is derived from "granitic and rhyolitic parent material" **(Kingsbury and Stoddard 1996: 5)**. Approximate average soil depth in the cultural zone on the first terrace was determined to be 33 cm by archaeologists using augers in 1978 **(Kingsbury and Stoddard 1996: 6)**.

Figure 5. *Google satellite image of White Creek site along the Middle Fork of the Salmon River. Dashed oval line denotes distribution of linear pit house depressions on upper terrace.*

White Creek is adjacent to a potential fording location on the Middle Fork River. Two depressions were test excavated (#3 & #7) by Trowbridge **(1989) (Fig. 7).** A total of seventeen projectile points or point fragments were recovered, twelve of which were diagnostic **(Trowbridge 1989)**. Approximately 500 bone fragments were recovered, most of which were "green fractured long bone" from native ungulates **(Trowbridge 1989)**. Contexts within the test pits showed signs of significant disturbance by historic and modern activity, but Trowbridge doubted that all nine depressions were disturbed **(1989)**. The site location combined with the recovered artifacts suggests that White Creek was a field camp occupied in the Middle to Late Prehistoric Period **(Trowbridge 1989)**.

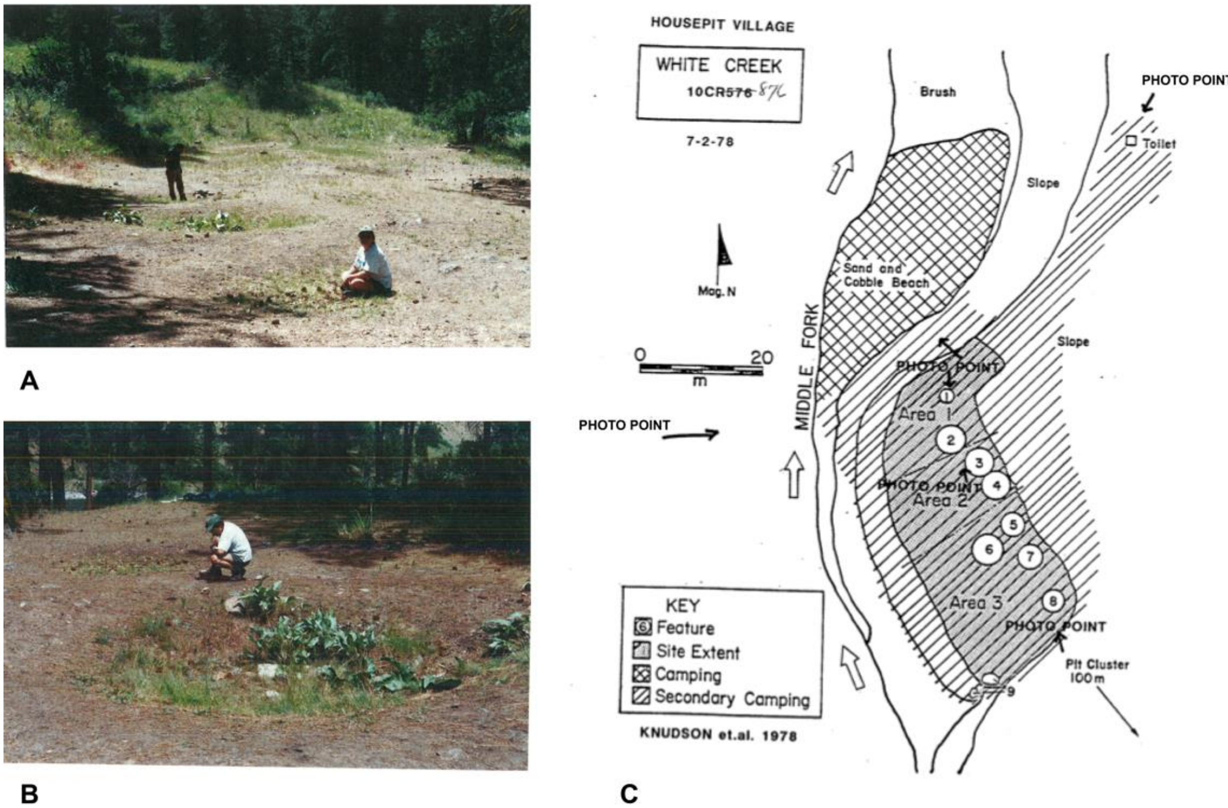
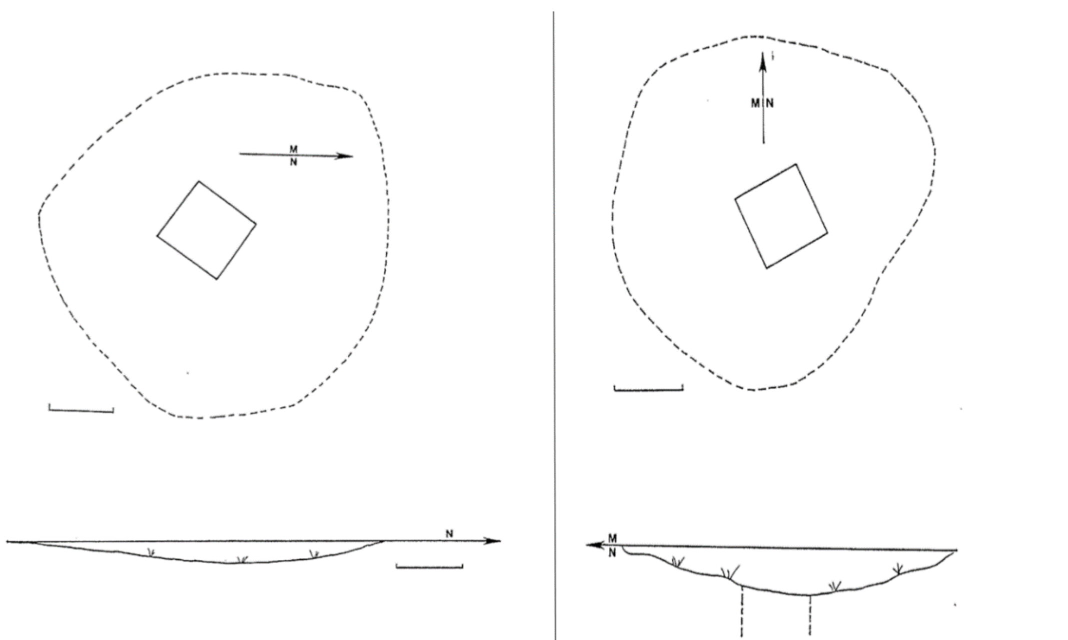


Figure 6. *A – picture of White Creek terrace with house depressions visible; B – picture of pit house depression #3; C – general plan of White Creek pit house site (after Knudson et al. 1978).*



Plan and profile of Test Pit A in pit house depression #7.

Plan and profile of Test Pit B in pit house depression #3.

Figure 7. *Plan and profile drawings of test pit excavations of pit house depressions at White Creek Site (Trowbridge 1989).*

The geology at the White Creek site in the Casto Quadrangle of Idaho is a collage of Eocene-age igneous rocks, collectively known as the Challis Volcanic Field **(Fig. 8) (Moye et al 1988: 89)**. The Challis Volcanic Field represents a series of bimodal eruptions and intrusions that occurred 55 Mya to 40 Mya **(Moye et al 1988: 87)**. Moye et al. generalize the eruption cycle in Central Idaho from oldest to youngest as “intermediate rocks; rhyodacite to rhyolite ash-flow tuffs; and rhyodacite to rhyolite domes and plugs” **(1988: 89)**. By comparing the location of the White Creek site to a USGS geologic map of Idaho in ESRI’s GIS map database **(Bond et al. 1978)** and Figure 2 in Moye et al. **(1988)**, the specific rock unit and rock type at the site’s location were determined. The geology at White Creek is part of the Casto Pluton and is comprised of granite to quartz monzonite, dacite dikes, and small syenite intrusions. At the location of the site specifically, pink granite ledges are visible along the sides of the river channel **(Moye et al. 1988: 15)** and this same unit is presumably the rock layer directly below the soil level at White Creek. While the White Creek site, as well as most known prehistoric sites in the Middle Fork, is not located on a high terrace, the alluvium at the site may be derived from older high terraces that were eroded and deposited downstream.

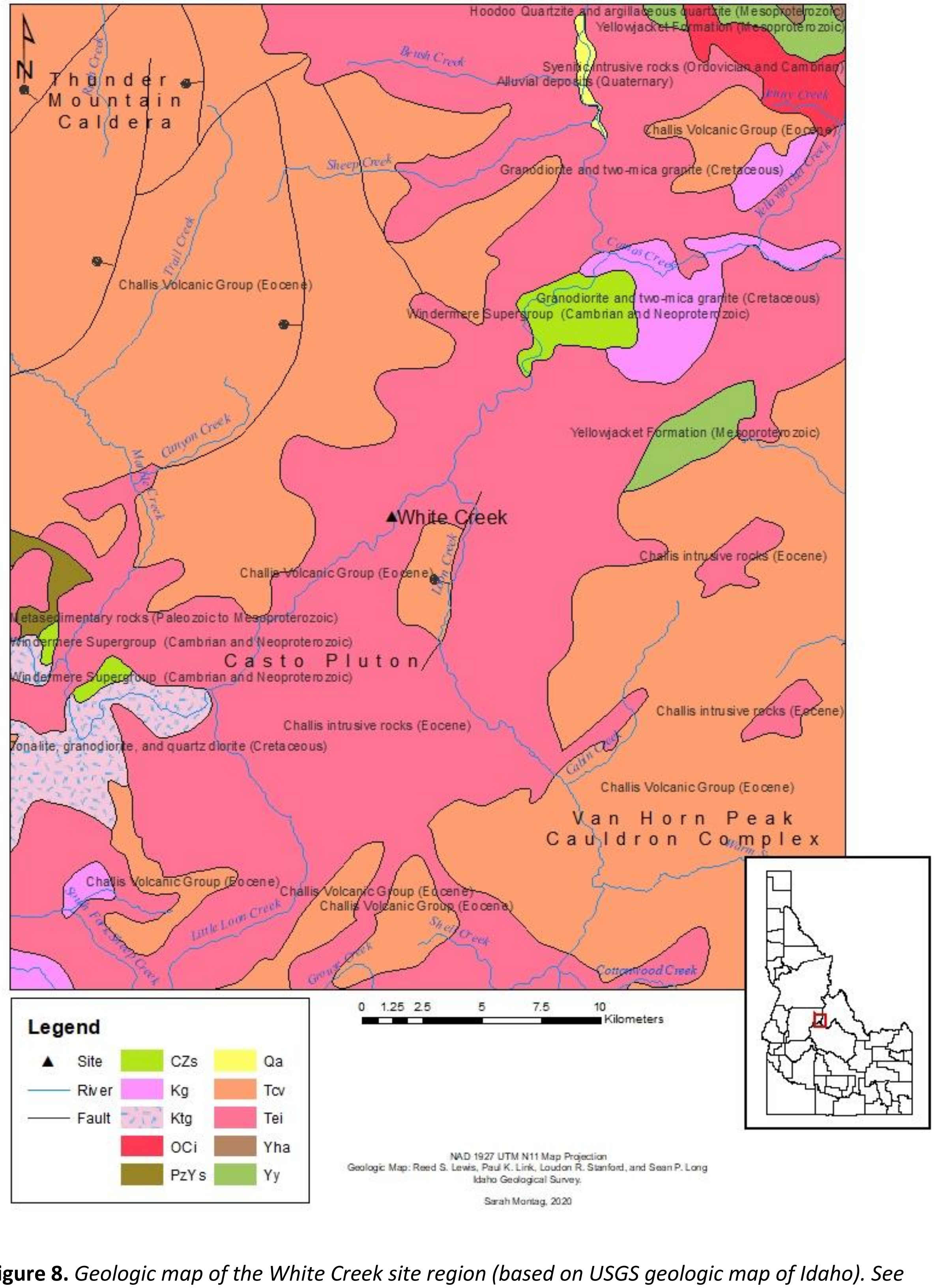


Figure 8. *Geologic map of the White Creek site region (based on USGS geologic map of Idaho). See Appendix for a detailed description of geologic units.*

When interpreting anthropogenic activity as trace element concentrations in soil, it is crucial to understand the composition of sterile soil **(Lubos et al. 2016, Dirix et al. 2013, Kern et al. 2015)**. Soil composition at the White Creek site is determined by parent material composition and depositional processes. The Casto Pluton, discussed above, and rhyolitic material south of the pluton associated with extrusive Challis Volcanic Group rocks are the parent materials of the alluvium on the river terraces of the Middle Fork of the Salmon River **(Kingsbury and Stoddard 1996: 5, Ross 1934, Moye et al. 1988: 89)**. The Middle Fork and minor tributaries like the White Creek erode the igneous rock and transport the material downstream within the steep Middle Fork alluvial valley **(Kingsbury and Stoddard 1996: 4, Ross 1934)**. The mineralogy of the granite at the White Creek site is an important contributing factor to elemental concentrations in the soil. The two major minerals, quartz and orthoclase, contain SiO_2, Al_2O_3, and K_2O, from highest to lowest relative concentration. Biotite and hornblende contribute MgO, Fe_2O_3, CaO, and Na_2O to the chemical composition of the granite. Because the bulk composition of the Challis Volcanic Field is relatively consistent across Central Idaho **(Moye et al. 1988: 89)**, the weight percent of major-element oxides for Eocene "pink granite" reported in Johnson et al **(1988: 60)** is an approximation of the composition of the Casto Pluton **(Table 4)**.

Table 4: *Mean weight percentage values of Eocene Pink Granite is used as an approximation for Casto Pluton composition. Wt % values from "Cretaceous and Tertiary Intrusive Rocks of South-Central Idaho" by Johnson et al (1988); ppm values calculated.*

	wt %									
	SiO_2	**Al_2O_3**	**Fe2O3**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**TiO_2**	**P_2O_5**	**MnO**
Eocene Pink Granite	75.6	13.1	1.19	0.2	0.58	3.3	4.87	0.11	0.05	0.02

	ppm									
	Si	**Al**	**Fe**	**Mg**	**Ca**	**Na**	**K**	**Ti**	**P**	**Mn**
Eocene Pink Granite	353380	69330	8320	1210	4150	24480	40430	659	218	155

The research presented in this BPhil Thesis focuses on analysis of soils collected from the White Creek site, specifically from Block 2 from the 2016 season survey. However, before discussing this in more detail, it is important to provide a general overview of the research conducted at the site by the MFGRP team.

5.1. 2015 Research at White Creek

The White Creek site was first investigated by the MFGRP team in the summer of 2015 and again during the 2016 and 2017 seasons. Although some methods were repeated at the site over multiple seasons, new instruments and additional soil coring were undertaken from year to year. Due to the excellent preservation of the topographical pit house depressions, and overall small size of the terrace, it was possible to undertake a fuller range of geophysical and geochemical study and this made White Creek a particularly favorable site for geophysical and geochemical analyzes **(Table 5)**.

Table 5. *Multi-seasonal research activities at the White Creek site.*

Season	Geophysics	Soil Sampling	Geochemistry
2015	Fluxgate gradiometry	Single transect (N=11)	HHpXRF [Pittsburgh - Doonan & Hanks 2016]
2016	Fluxgate gradiometry, mag susc and electrical resistance	Block sampling (N=36) Two transects (N=16)	HHpXRF (subsurface samples, Pittsburgh)
2017	Fluxgate gradiometry, CMD Mini-Explorer, Bartington mag susc.	limited soil sampling (feature)	HHpXRF (surface soils)
2019-2020	Bartington mag susc. (subsurface samples)	-	HHpXRF and soil geochemistry extractions (Pittsburgh)

In 2015, seven 10 m^2 survey blocks were oriented along a baseline at magnetic 72˚/252˚ parallel to the line of depressions and the Middle Fork River. GPS coordinates of the block corners, pit centers, and soil sample locations were recorded with a hand-held Trimble GeoXT; all coordinates were differentially corrected using the Pathfinder post-processing feature. A fluxgate gradiometer survey was completed over the 7 blocks and a single transect of soil samples (N=11) was taken with a 5/8” diameter t-handle soil probe **(Fig. 9)**.

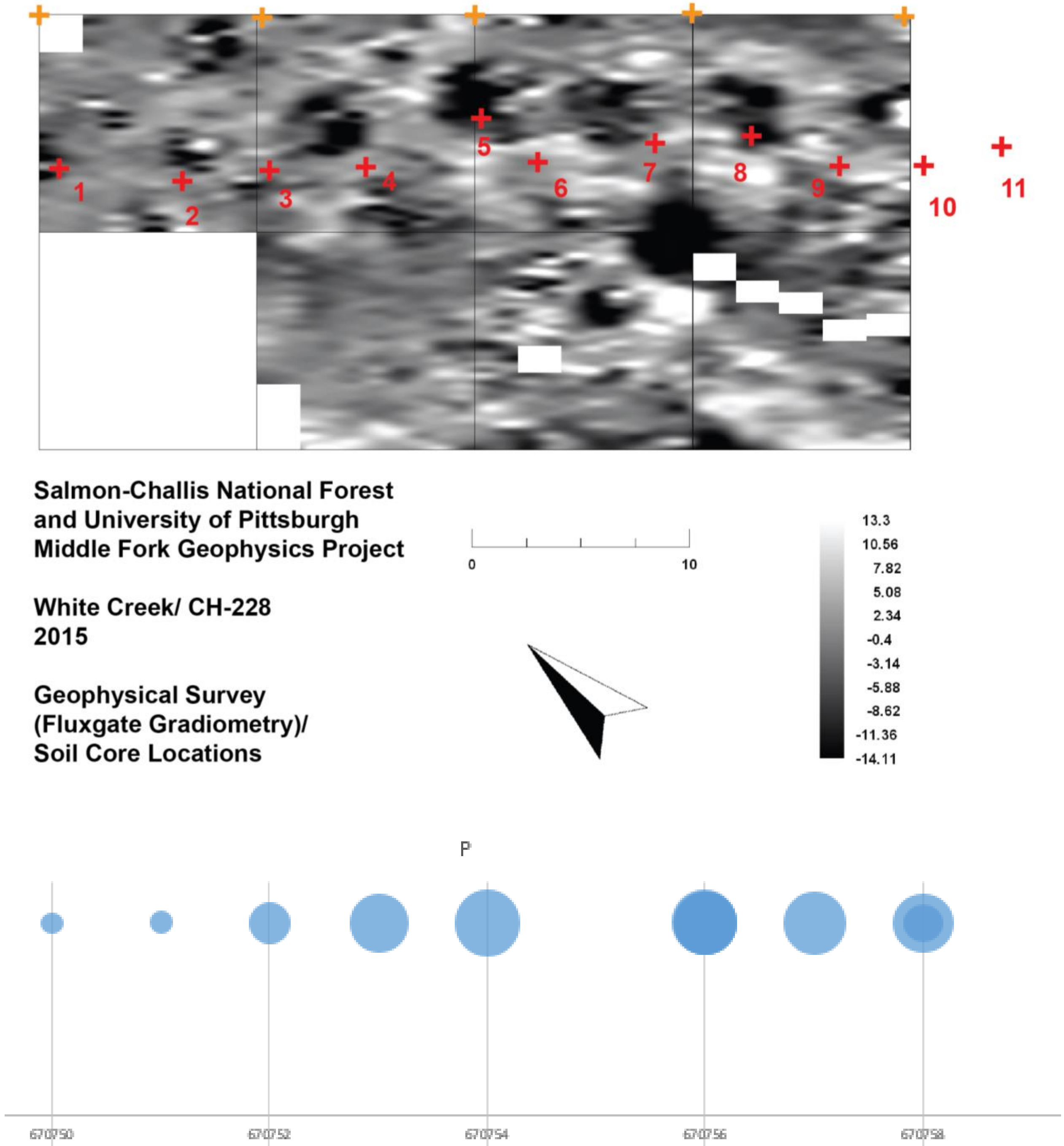


Figure 9. *Upper Image - Greyscale plot of fluxgate gradiometer survey at the White Creek site. Dark circular features represent pit house features and nT scale has been reversed (features are negative nT) for better visibility. Red crosses denote location of soil collection probes taken approximately at 5 m intervals; Lower Image - Phosphorus concentration variability in White Creek 2015 soil samples #1-9 analyzed with HHpXRF (after Doonan and Hanks 2016).*

Following the 2015 season, Dr. Roger Doonan and Dr. Bryan Hanks **(2016)** analyzed the 11 soil samples that were collected with a Niton XLT3 instrument. The method utilized the "mining mode" with a 135 second integration time per sample and the use of a helium purge for improved detection of light elements, such as phosphorous **(Doonan & Hanks 2016)**. In this initial pilot study, it was determined that phosphorus concentration varied across the cultural occupation zone of the terrace and that phosphorous was elevated in soil samples collected near or within pit house depressions areas **(Fig. 9)**. Doonan and Hanks **(2016)** reported that:

> *"The key elements assessed are very much standard indicators of human activity (P, Cu, Zn and Pb). As stated above there seems clear structured patterning in other elements especially Cl, S, Bi and sometimes Sr, Cr and V. These are certainly not standard anthro-indicators but such elemental distributions are very much dependent on local and regional geology. Without current insight of local geological conditions and with the relatively low sample numbers it is not considered sensible to pursue these datasets at this present time although they remain in the archive for further consideration"*
>
> **(Doonan and Hanks 2016: 6)**.

These results indicated that multi-element analysis using HHpXRF had the potential to offer an important new method for rapid in-situ characterization of soils at prehistoric and historic sites along the Middle Fork River. And, that such data might better inform an understanding of both natural and cultural effects to soils and multi-element patterning within them.

5.2. 2016-2017 Research at White Creek

In 2016, the MFGRP team returned to White Creek to carry out additional multi-instrument geophysical survey and soil sampling for later ex-situ analysis. Seven 10 m^2 survey blocks were oriented along a baseline at magnetic 72˚/252˚ parallel to the line of depressions and the Middle Fork River **(Fig. 10)**. Blocks 1-4 overlap the original survey area from 2015. GPS coordinates of the block corners, pit centers, magnetometry calibration location, and resistivity calibration location were recorded with a hand-held Trimble GeoXT.

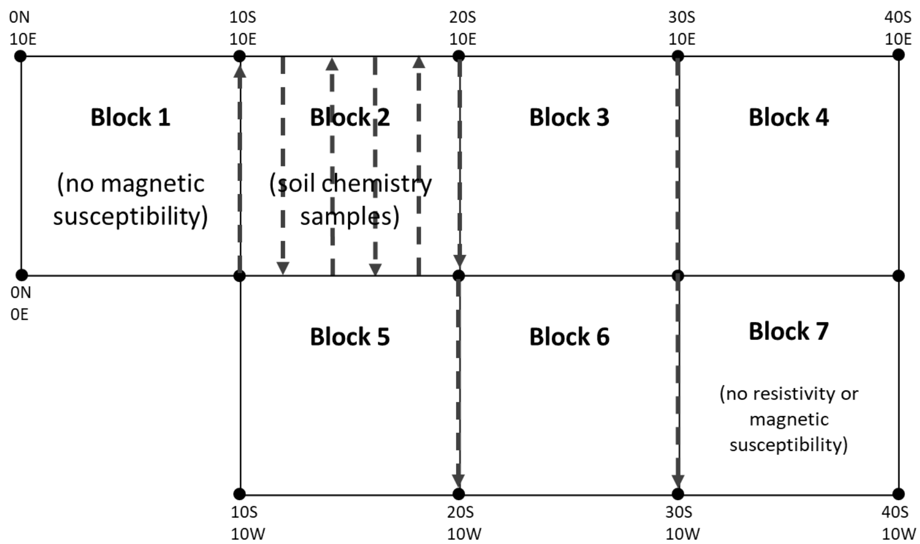


Figure 10. *2016 White Creek Survey Schematic. Blocks are 10 x 10 m. Gradiometry, resistivity, and magnetic susceptibility surveys completed at all blocks unless otherwise stated. Dashed lines indicate locations of soils samples taken at 2 m intervals. Adapted from Canaday MFGP field notes (Canaday 2016).*

Gradiometry surveys were conducted first with a sampling density of 0.5 m x 0.125 m. An earth resistance survey also was conducted in Blocks 1-6 at a 1 m x 1 m sampling density. A total of 36 soil samples using a 5/8" diameter T-handle soil probe were collected at 2 m intervals in Block 2. Two additional transects were sampled at 2 m spacing on the 20S survey line and the 30S survey line across the site. In total, 52 soil samples were collected from the site that season. The depths of the samples were recorded and the average depth below the vegetation level was determined to be approximately 11 cm.

Researchers returned to the site again in 2017. Four 10 m^2 survey blocks and one 10 m x 5 m survey block were oriented along a baseline at magnetic 161˚/341˚ parallel to the base of the terrace slope. These survey blocks encompassed the main house pit depression area, as in previous seasons **(Fig. 11)**. GPS coordinates of the block corners and pit centers were recorded with a hand-held Trimble GeoXT GPS unit.

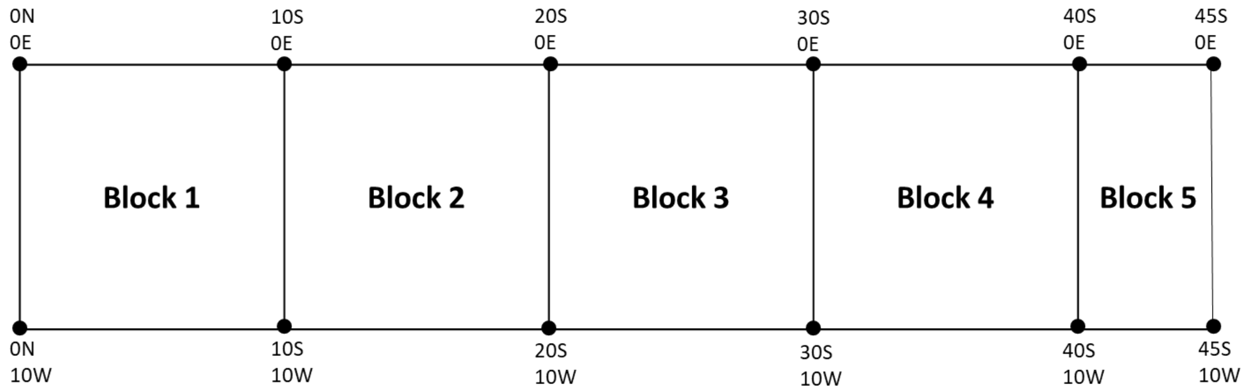


Figure 11. *2017 White Creek Survey Schematic. Blocks are 10 x 10 m. Gradiometry, conductivity, magnetic susceptibility, and HHpXRF surveys completed at all blocks. Adapted from Canady MFGRP field notes 2017 (Canaday 2017).*

During this season, the MFGRP team completed additional geochemical and geophysical surveys in several of the grids. This included fluxgate gradiometry (1 m x 0.125 m sample density) in Blocks 1-5, magnetic susceptibility of surface soils (2 m sampling density) in Blocks 1-2, electromagnetic conductivity and in-phase magnetic susceptibility at .25, .50 and 1.0 m depths (1 m sampling density) in Blocks 1-4, and HHpXRF analysis of surface soils (2 m sample density) in Blocks 1 & 2. Topographical survey, using a dumpy level, was also conducted in Blocks 1-4.

In sum, the multi-instrument geophysical surveys conducted at the White Creek site during the 2015-2017 seasons indicate important variation in responses across the site and suggest the presence of subsurface and surface anomalies adjacent to visible house depression features. This suggests the possibility of related prehistoric and/or historic anthropogenic features (e.g. pits, hearths, activity zones, etc.). Data from these surveys are summarized in **Figure 12**. Following these studies, the logical next step was to undertake a more detailed geochemical study of recovered soils at White Creek. It was determined that sub-surface soils that were collected during 2015 and 2016 could be used and that this would provide an important opportunity to more fully examine the effectiveness of geophysical and geochemical studies of surface and subsurface soils at the site. This provided an excellent opportunity for the author to develop a BPhil Thesis project focusing on these issues and to contribute a new line of data and set of interpretations to the collaborative project.

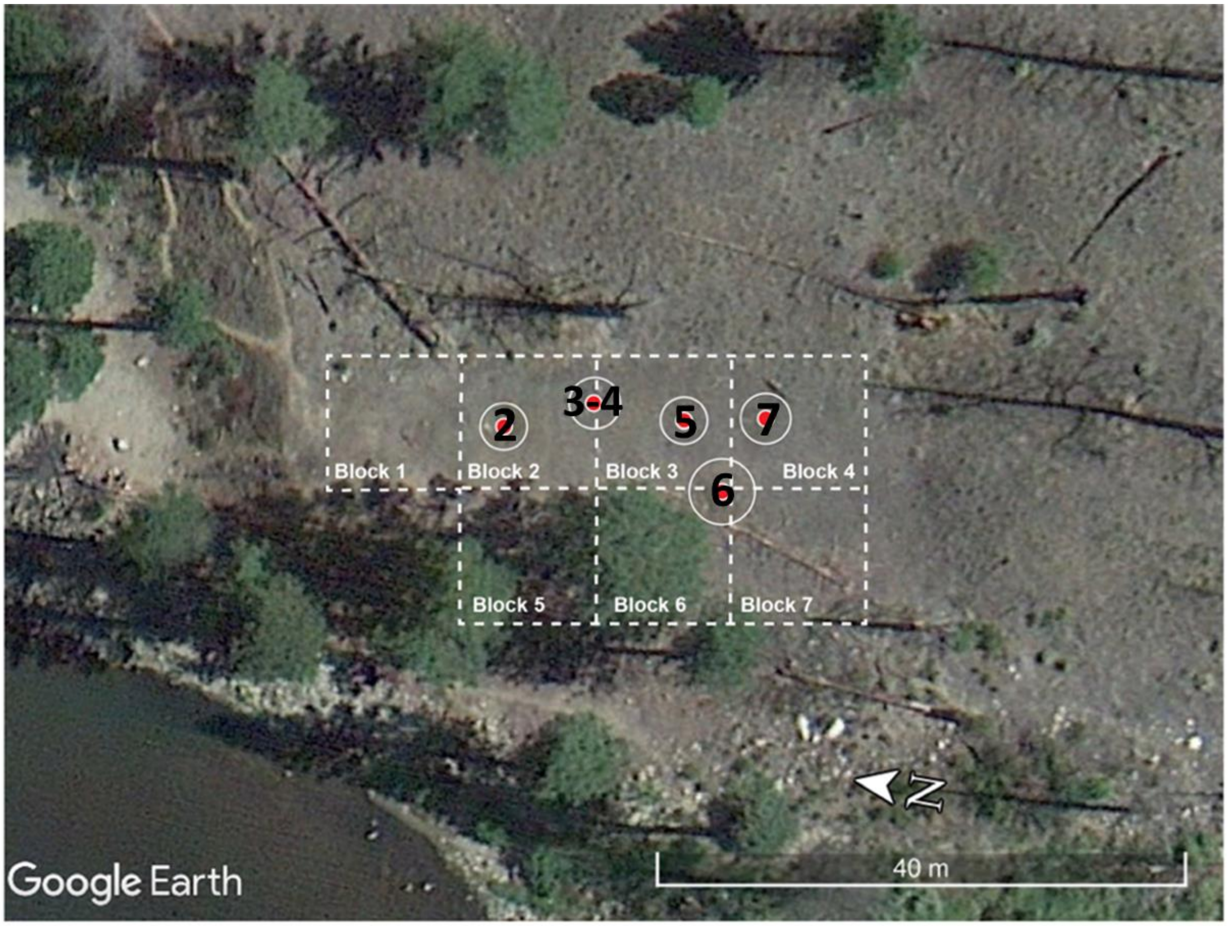


Figure 12. *Satellite image of the White Creek site with 2016 survey blocks and locations of depressions overlaid. Depressions are labeled to reflect Knudson et. al. 1978 site map.*

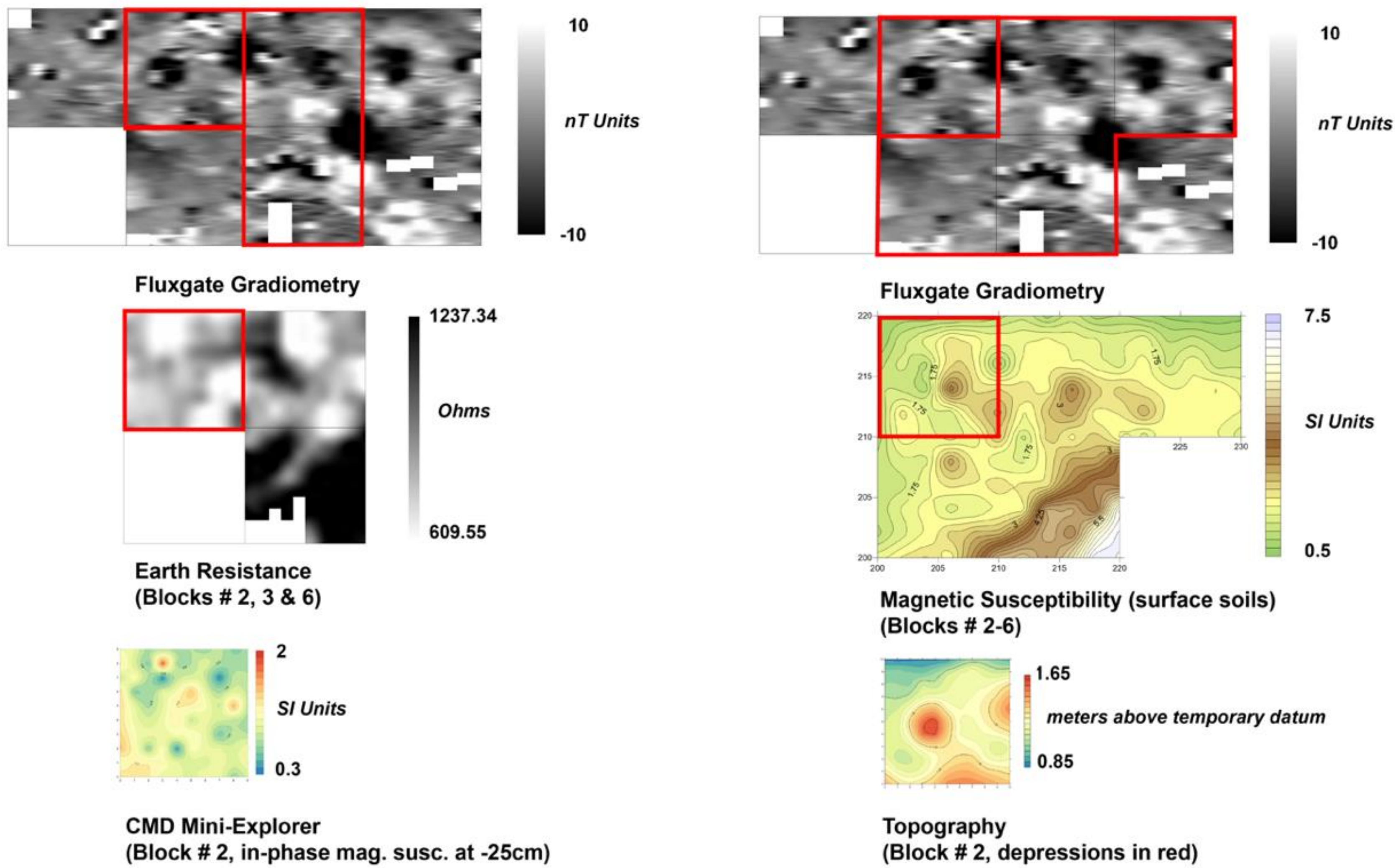


Figure 13. *Plots of multi-instrument geophysical surveys at White Creek from the 2015-2016 seasons indicating pit house depressions and multiple anomalies adjacent to them in Blocks # 2 - # 6 (after Canaday et al. 2017).*

6. BPhil Thesis Research

New analytical studies relating to the BPhil Thesis research focused specifically on the soil samples from Block #2 (n=36) that were collected systematically every 2 m in 2016. These samples were analyzed by the author for qualitative soil characteristics including: Munsell color, composition, average grain size, and presence/absence of ecofacts like charcoal and ash (see Appendix for full description of soil samples). The sampled soils are primarily grey-brown in color. The soil compositions range from silt, silt-loam, sandy loam, and loamy sand. Soil samples collected near the base of the slope of the second terrace along the east edge of Block # 2 are composed of shallow, very-fine-grained silt. Soil composition in the cultural zone (pit house depression features) is variable.

Sample composition varied across Block # 2. Samples composed of coarser soils were generally heterogeneous in grain size and mineralogy whereas very-fine-grained samples were homogeneous in these regards. Major mineral constituents include quartz, micas, and pink feldspar grains. Only one sample (#22) included charcoal. Several samples (#3, 4, 5, 18, and 19) had an extremely airy texture and a dull grey color. These samples were interpreted as containing ash. One soil sample (#8) included an obsidian debitage piece. Another possible artifact was recorded from sample #17. This soil sample included a 3 mm long, angular, white, siliceous flake **(Canaday 2016)**. The spatial distribution of artifacts and ecofacts in Block # 2 are detailed in **Figure 14**.

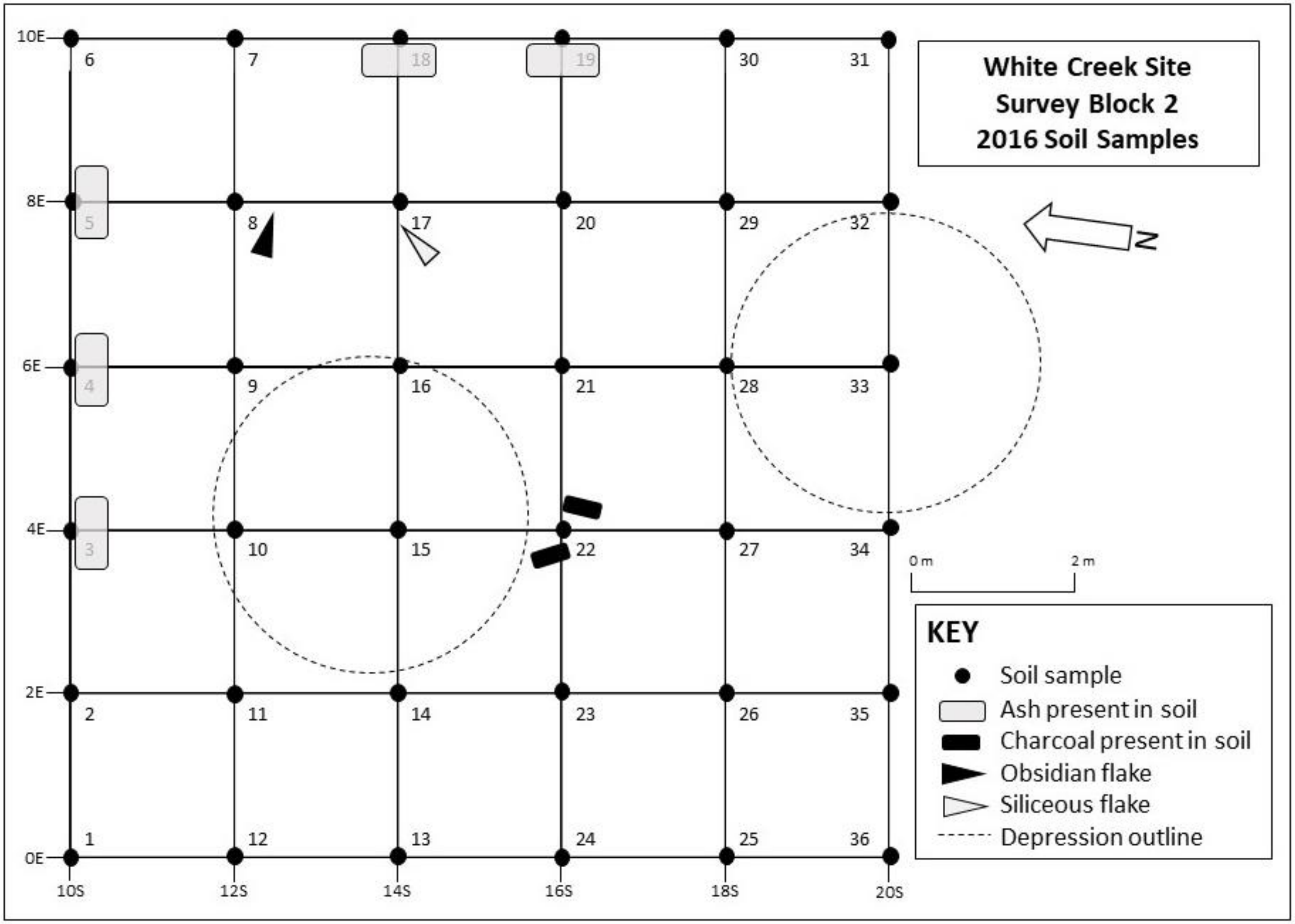


Figure 14. *Survey Block 2 (2016) of the White Creek site. Adapted from Dr. Canaday's 2016 MFGRP field notes (Canaday 2016).*

6.1. Benchtop HHpXRF and Magnetic Susceptibility

The 36 soil samples collected in 2016 from survey Block 2 at White Creek were analyzed twice using HHpXRF. Soil samples were collected at two-meter intervals in the 10 m by 10 m survey block. Duplicates of three of the samples were created following the method described below in section 6.2 in order to assess the accuracy of the analytical instruments used in this research. Duplicates of samples 11, 22, and 33 were created in the laboratory at the University of Pittsburgh for a total of 39 samples. Soil preparation for laboratory analyses began by emptying bagged samples into paper boats. Samples were air-dried at room temperature for three days. Samples were then sieved with a 2mm standard sieve to remove pebbles and organic roots. Samples were split to ensure homogeneity of grain size with the following method: two pieces of clean standard printer paper were placed on a flat surface with one edge overlapping. The soil sample was poured on the overlapping edge and the two pieces of paper gently poured apart to split the sample. This process was repeated until a split sample of approximately 10 cubic centimeters (cc) was obtained. The split samples were transferred to clean 10cc standard cylindrical plastic containers with plastic membranes on the bottom in batches of eight. Soil was lightly packed into the containers and a lid was gently placed on each container.

Subsequent HHpXRF analyses were performed using a Niton™ XL3t GOLDD+ XRF Analyzer, first in March of 2018 by Dr. Bryan Hanks and in October 2019 by the author. The instrument was recalibrated by the manufacturer in the time between the analyses. The same methods described below were used in both the 2018 and 2019 analyses. The HHpXRF analyzers were secured in a lead-lined integration box specifically for laboratory use of the instrument. A systems check was performed before analyzing samples. Four standard samples USGS (#180-706), NIST (#180-649), RCRA (#180-661), and SiO_2 (#180-647) were analyzed and compared to known elemental concentrations in a Certificate of Analysis provided by Thermo Scientific for Niton XRF Analyzers. This was done to assess instrument daily accuracy and drift. The entire batch of soil samples (n=39) were analyzed using a range of filters and the instrument's in-built Fundamental Parameters calibration. First, the soil samples were analyzed using "Mining Mode" with four filters selected: "Low" (10 seconds), "Main" (10 seconds), "High" (10 seconds), and "Light" (60 seconds). The emphasis in this particular mode was on "light elements", such as phosphorous, and therefore longer integration times were not used for the other filters. Because only eight sample containers were available, after a sample was analyzed, the soil was transferred to a paper sample boat and any remaining dust in the container blown out before the next sample was prepared.

After the 39 samples were analyzed on "Mining Mode", the instrument was adjusted to "Soils Mode" with three filters selected: "Low" (60 seconds), "High" (60 seconds) and "Main" (60 seconds).

Lastly, the four standard samples were analyzed once more. Data from both the 2018 and 2019 HHpXRF analyses are available in the Appendix.

The same 39 White Creek soil samples also were analyzed for magnetic susceptibility using a benchtop method in September of 2019 by the author. Samples were dried and split using the same methods described above for benchtop HHpXRF. Once an approximately 10 cc soil sample was acquired, the soil was transferred to a standard plastic cup, gently packed down with a 15 mm diameter wooden dowel rod and secured with a lid. The masses of the soil samples in the plastic cups were recorded and the masses of the samples were calculated to one decimal point accuracy using the mass of an empty sample cup. This data is included in the Appendix.

A Bartington MS2 Magnetic Susceptibility Meter with an MS2B Dual Frequency Sensor was used for analysis. Soil samples were analyzed at the 1.0 accuracy level using SI units with both the low frequency and high frequency settings. Before analyzing the soil samples, the instrument was calibrated with a MS2B LF/HF Calibration Sample (magnetic susceptibility of 3057 cgs). Three measurements were taken for each sample for each frequency setting and the median measurements were reported.
Data from the 2019 benchtop magnetic susceptibility analysis is available in the Appendix.

6.2. Soil Extraction Chemistry

The soil extraction method used for this research is adapted from Homsey and Capo **(2006)** and modified by Dr. Rosemary Capo and Dr. Brian Stewart of the University of Pittsburgh. Samples collected in the field were placed in paper boats and allowed to dry at room temperature for at least three days. Compacted soil was gently crushed with a rolling pin between wax paper. Samples were sieved with a 2 mm standard sieve to remove pebbles and organic roots. Samples were then split using a dry splitter to produce a 1-2 g homogenous sample. The splitter was cleaned with ethanol between samples. Homogenous samples were transferred to small glass jars of pre-recorded mass. Mass of the jar and the sample was recorded to three decimal places and the mass of the sample calculated.

Samples were then transferred to 50 mL polypropylene centrifuge tubes and 20 ml of ammonium acetate (NH_4Ac) (approximate pH of 8.14) per gram of sample was added to each centrifuge tube. Centrifuge tubes were agitated for one hour and centrifuged at 4000 rotations per minute (rpm) for 15 minutes. The extractions were filtered from the centrifuge tubes using the setup shown in **Figure 15**.

Figure 15. *A 60 ml poly syringe with an attached filter held up with a ring stand above a 60 ml poly sample bottle of previously recorded mass (author's photo).*

A clean 1 ml pipette tip was used for each sample to transfer the extraction liquid from the centrifuge tube to the syringe. A syringe plunger pushed the liquid through the filter into the bottle. After all samples were filtered using this method, with clean equipment being utilized for each sample, approximately 20 ml of milli-Q water (MQW) was added to each of the centrifuge tubes. The centrifuge tubes were agitated and centrifuged at 4000 rpm for ten minutes. The same filtering process was repeated for every sample using the same equipment that was initially used.

Extractions were transferred to rinsed and labeled 50 ml polypropylene test tubes. Test tubes were placed in a heated evaporator and the caps removed. Extractions dried at 90 ˚C for 24 hours until completely dry. 20 ml of 2% nitric acid (HNO_3) was added to solid contents of test tubes and agitated. After 24 hours, solids had not dissolved entirely at this acid concentration, so they again were dried down using the evaporator. Once the test tube contents were dry, 1 ml of concentrated HNO_3 and 1 ml MQW (50% HNO_3) were added dropwise to each tube. Tubes were gently agitated and left undisturbed for 24 hours. After solids had completely dissolved, the test tubes were placed in a sonicator for 30 minutes in batches. 48 ml of MQW were added to the test tubes to bring the HNO_3 concentration to the target 2% required for analysis by ActLabs. The extractions were transferred to the labeled and cleaned 60 ml poly bottles and the final mass of the bottle and extraction was recorded. The mass of the extraction was calculated.

ActLabs analyzed the samples using their Method 6-Hydrogeochemistry **(Hydrochemistry n.d.)**. Samples were analyzed with "Perkin Elmer Sciex ELAN 9000 ICP/MS, Perkin Elmer Nexion, Thermo icapQ or Agilent 7700" **(Hydrochemistry n.d.)**. Concentrations are reported as (µg/L) and detection and upper limits vary depending on element **(Hydrochemistry n.d.)**. **[*Note – data is yet to be received from ActLabs]**

7. Results

Unfortunately, the results of the soil chemistry extractions were not received in time to be integrated within this thesis. Therefore, a discussion of the final results of the author's research will focus on the magnetic susceptibility measurements and HHpXRF data in comparison to the previous geophysical surveys at the White Creek site. This discussion will detail the results of research with the soils from Block 2, however, a broader discussion of their interpretation will be provided in responding to the research questions that structured the BPhil Thesis research.

7.1. Soil Magnetic Susceptibility

As outlined above, detailed magnetic susceptibility of the soils from Block #2 at White Creek were completed **(Fig. 16)**. Elevated magnetic properties in soil can be explained by natural pedogenic processes and/or anthropogenic activity. Magnetic enhancement is caused by the transformation of hematite to the increasingly magnetic magnetite and maghemite in sequential reduction and re-oxidation chemical reactions **(Aspinall et al. 2008: 24)**. These reactions in soils can be triggered by five processes: burning fires; bacteria breakdown of organic waste; concentrations of "magnetotactic bacteria;" addition of magnetic materials, particularly associated with metalworking; and pedogenesis **(Aspinall et al. 2008: 24-25)**.

The first four of these triggers are associated with anthropogenic activity. In the case of the White Creek site, heightened soil magnetic properties are not caused by the addition of magnetic materials. No metal working occurred at the site in prehistory, and any historic/modern addition of magnetic material, such as discarded nails and other ferrous debris, for example, would produce a single elevated point in the data. It is unlikely that elevated magnetic values are the result of "magnetotactic bacteria" as well, because these bacteria are associated with in-situ decay of organic material like wooden posts or large middens **(Aspinall et al. 2008: 25)**. Dense concentrations of magnetotactic bacteria produce only subtle elevations in the magnetic susceptibility of soils **(Aspinall et al. 2008: 25)**, so it is unlikely that magnetic susceptibility variation at the White Creek site is primarily the result of this process.

This suggests two anthropogenic explanations for magnetic variation in the soils at the White Creek site. These explanations are supported by known prehistoric activities: burning fire for heat/food processing and the concentration of waste in middens and/or pit features **(Aspinall et al. 2008: 24)**.

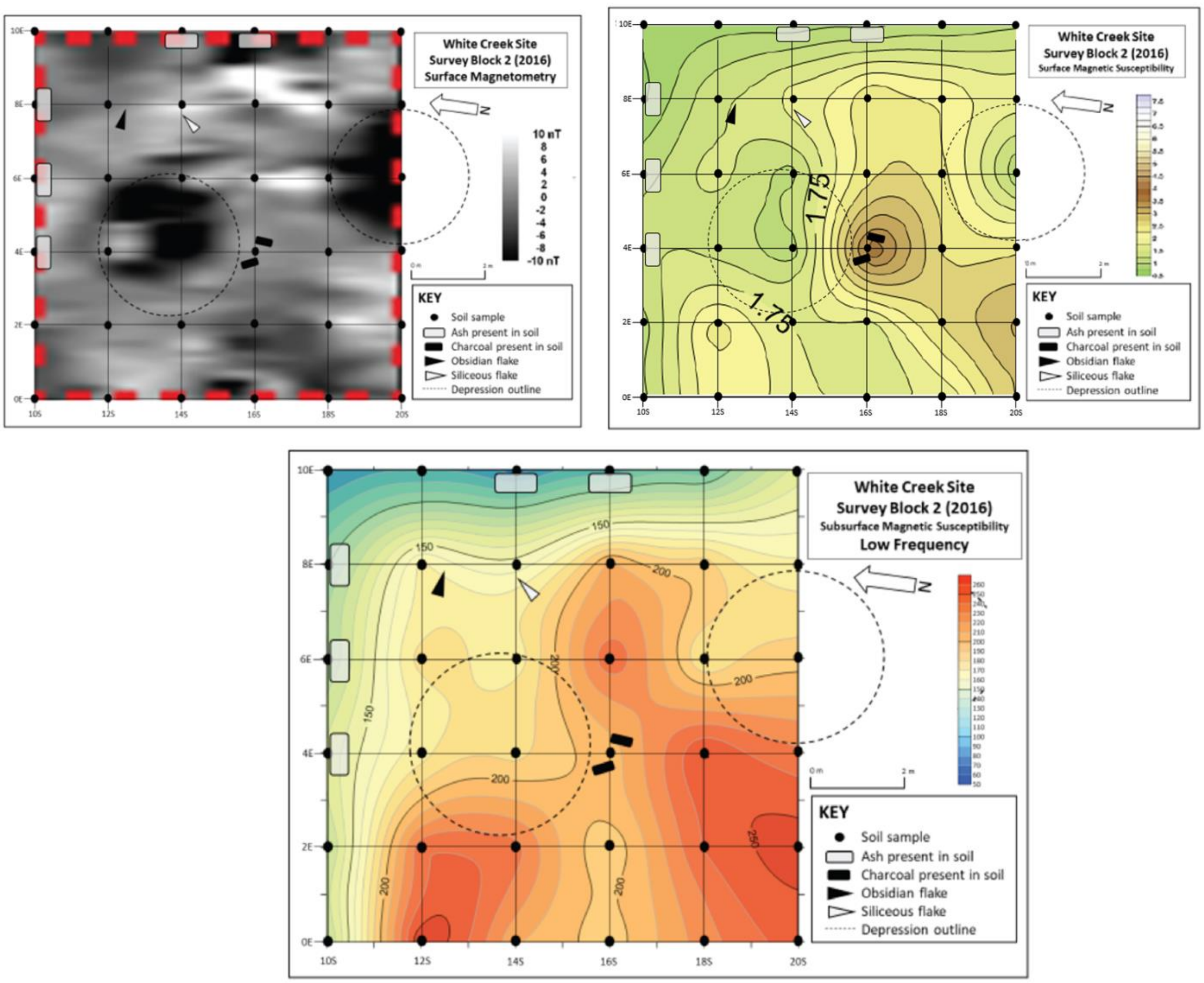


Figure 16. *Upper Left – fluxgate gradiometry of Block #2 showing location of soil core samples; Upper Right – surface magnetic susceptibility results of Block #2; Lower – subsurface magnetic susceptibility results of soil core samples from Block #2.*

7.2. HHpXRF Analysis Results from White Creek Block #2

Exploring evidence of prehistoric anthropogenic activity in soils sampled at the White Creek site focuses on eight key elements: P, Ba, Sr, K, Mn, Zn, and Mg. This element suite reflects the elements that Homsey and Capo **(2006: 247)** focused on in a similar geoarchaeological investigation at an Archaic rockshelter site in Alabama where cultural activities were comparable to those at campsites in the Middle Fork Valley. Prehistoric occupants at both of these sites prepared food took shelter within the natural rockshelter in Alabama and in built, semi-subterranean houses in Idaho.

It is common to utilize geochemical survey techniques to determine site spatial extent. Because the White Creek site occupies a narrow terrace and is demarcated by distinct surface features, determining on-site/off-site zones is not applicable to this study. As discussed previously, soil sampled from Block 2 of the White Creek site is included in this analysis. Characterizing prehistoric activity zones in detail within this sampled area is more valuable for understanding this site. The spatial distributions of elemental concentrations listed above are analyzed below in the order listed previously.

Phosphorus (P) is the most referenced element in geoarchaeology studies, particularly in prospective surveys **(Holliday and Gartner 2007)**. Unlike other elements, P is relatively immobile once it is added to soil and affixes to other elements to form phosphate minerals. Once fixed in phosphates, the P remains in place over a geologic time scale and is therefore a good indicator of occupation density over the scale of thousands of years **(Holliday and Gartner 2007: 302)**. Although no "sterile" soil samples were collected from the field for analysis, the approximate concentration of P in Eocene pink granite, the parent material of the soil at the White Creek site, is 218 ppm (see **Table 4**).

Schuldenrein **(1995: 123)** quantifies the relationship between P concentration (in mg/kg, which is equivalent to ppm), and occupation intensity: "10 to 300 mg/kg, hack farming and ranching; 300 to 2000, dwelling, gardening, manufacturing, and garbage dumping; >2000, burials, refuse pits, slaughter areas, and urban living." Schuldenrein emphasizes that these values are generalized but are supported by several geoarchaeological studies at prehistoric sites **(1995)**. The highly varied activities Schuldenrein **(1995)** describes affect the landscape differently within each culture, period, and location. This characterization of P concentrations is likely problematic, especially when extrapolated to prehistoric campsites. However, the P concentrations detected with HHpXRF at White Creek appear to correlate with the ranges described above. For example, 78% of the samples contain P at concentrations higher than 2000 ppm associated with "burials, refuse pits, and slaughter areas." High P concentrations are clustered around the two pit house depressions and between the depressions and the edge of the terrace near the river **(Fig. 17)**. The measured concentrations are slightly higher than expected based on this range, especially because dwellings are associated with smaller concentrations. By instead using P concentration as a proxy for general, repeated human occupation, as Frahm et al **(2016)** suggest, the HHpXRF results at White Creek are within the expected range. By first confirming P concentrations at an expected level associated with prehistoric occupation, more detailed analyses with this element can be performed.

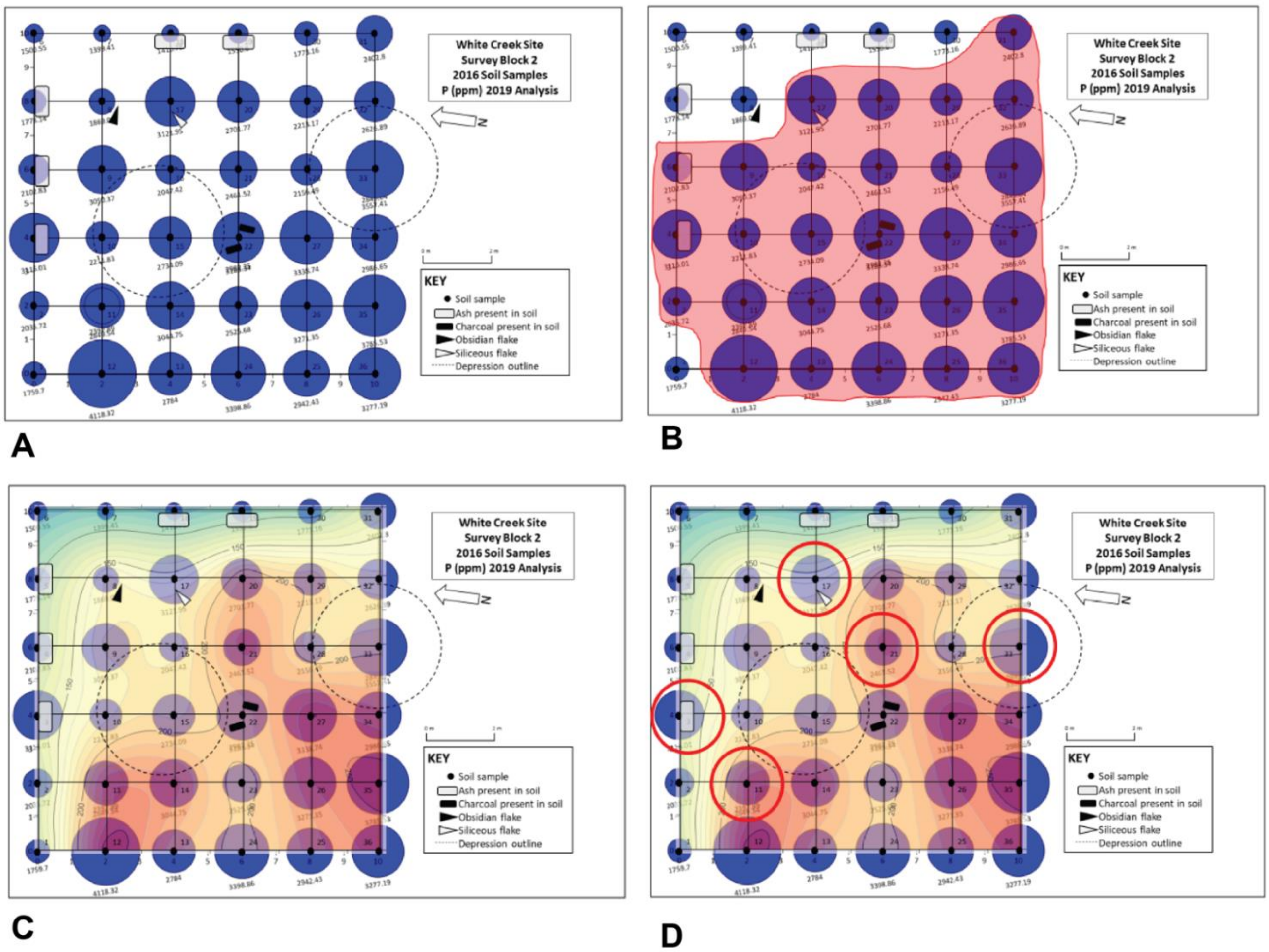


Figure 17. *A – P concentrations of soil samples from Block 2 detected by HHpXRF; B – P concentrations greater than 2000 ppm highlighted in red; C – Phospohorus concentrations detected in soil samples and interpolated magnetic susceptibilty of soil samples; D – Samples (3, 11b, 17, 21, and 33b) with anomalously large residuals are circled in red.*

7.3. Comparative Analysis and Discussion

Researchers **(Homsey and Capo 2006, Marwick 2005)** have productively examined the correlation between magnetic susceptibility variation and phosphorus concentration to study prehistoric site spatial activity and occupation intensity. A regression analysis performed in Microsoft Excel indicated a moderately strong, positive, linear relationship between P concentration and magnetic susceptibility of the White Creek, Block 2 soil samples (n = 39; $R^2 = 0.6346$; $p < 0.001$ at the 95% confidence level) **(Fig. 18)**. The results of this regression analysis suggest that the HHpXRF and magnetic susceptibility methods used in this research are valid. However, there are samples with high residual values that cannot be ignored. Samples 3, 11b, 17, 21, and 33b have residual values greater than |50| (average residual value is |29.93|). Samples 3, 17, and 33b are negative residuals and samples 11b and 21 are positive. Sample 3 contained ashy soil, and sample 17 is associated with siliceous debitage; these associations may relate to the discrepancy between the P concentration and magnetic susceptibility of the soils. Similarly, sample 21 is near a sample that contained charcoal and is located between the two pit house depressions. It is interesting that samples 11b and 33b produced different P concentrations than their duplicates, resulting in high residual values. Such variation is likely the result of individual particles enriched in P exposed at the membrane of the sample cup used for HHpXRF analysis. While the duplicate samples came from the same field sample, mineral heterogeneity within the soil could produce the variability reported. By adopting a research strategy of using multiple analytical methods, no individual result can influence the conclusions made by the researcher.

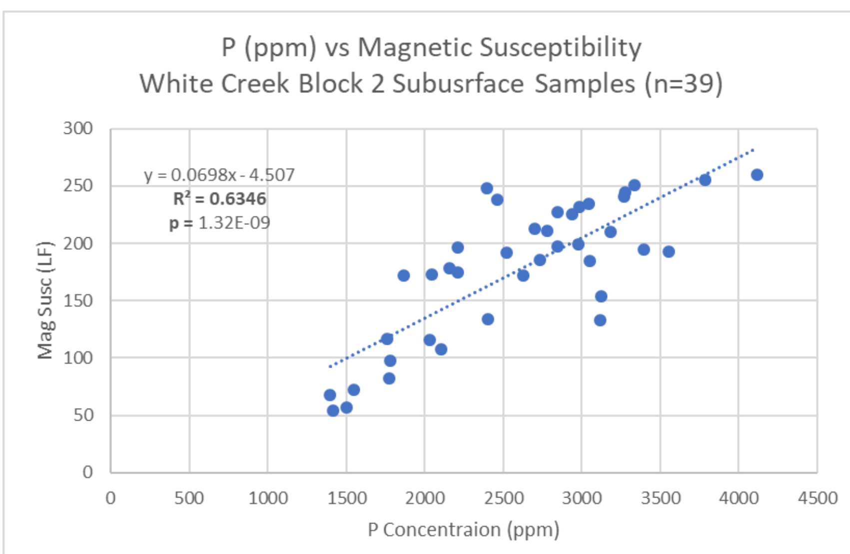


Figure 18. *Scatterplot of P concentration versus magnetic susceptibility of soil samples with linear regression line plotted and statistics included.*

Phosphorus concentration is most commonly used as a proxy for occupation intensity as discussed above, but researchers have identified specific activities/artifacts/ecofacts that are associated with variations in P concentration in anthrosols **(Holliday and Gartner 2007: 302)**. For example, P concentration has been found to correlate with lithic scatter density **(Homsey and Capo 2006)**. Previous archaeological surveys at the site reported dense surface lithic scatters around the pit houses **(Knudson et al 1982: 94, 113, Pavesic 1978: 24, Kingsbury and Stoddard 1996)**. The Trowbridge **(1989)** test pit excavation of two of the depressions (#3 & #7) recovered 17 projectile points among hundreds of debitage artifacts. Unfortunately, the precise spatial data for the lithic scatters described in the literature is unavailable. Only two lithics are reported in the data used for this study and are therefore unrepresentative of the known lithic concentration at the site. No statistical analysis relating lithic concentration to P variability is possible in this study.

While a lack of data prevents relating artifacts to P variability, there are ecofacts to compare with. Homsey and Capo **(2006)** and Schuldenrein **(1995)** report an inverse relationship between P concentrations and the presence of ash in soil at prehistoric sites. Five soil samples (samples 3, 4, 5, 18 and 19) contained ash determined by color and texture differences in comparison with the other samples. A two-sample, two-tail t-test comparing the five ashy soils to the 31 non-ashy soils assuming equal variances was performed in Microsoft Excel. The five samples with ash (M = 1992.87, S.D. = 679.5451) compared to the 34 without ash (M = 2686.926, S.D. = 648.4228) contained significantly lower P concentrations, $t(37) = -2.223 = 0.0324$ at the 95% confidence level. Although the ashy soil sample is small (n = 5), the t-test results agree with the conclusions made in other geoarchaeology studies. Phosphorus concentrations in these samples, coupled with physical characteristics of the soil, suggest that repetitive burning in hearths occurred at or around these points in prehistory.

High concentrations of P in soil is specifically associated with food processing and animal remains **(Homsey and Capo 2006, Schuldenrein 1995)**. Artifacts recovered from the White Creek site, specifically projectile points and charred animal (likely mountain sheep) bone, suggest that it was used as a seasonal hunting camp **(Knudson et al 1982, Pavesic 1978, Kingsbury and Stoddard 1996, Trowbridge 1989)**. Phosphorus concentrations are high in the study area based on the 39 samples in this study, but because P is an indicator of general occupation intensity, analysis of other elements must be incorporated to identify specific activity zones.

From the surface, the only indication of the site's existence is the line of house pit depressions. Because these are the most distinct features, a two-sample, two-tail t-test assuming unequal variances comparing the eight samples collected from within the depressions (samples 10, 15, 16, 28, 32, 33a, 33b, and 34) to the other 31 assuming equal variances. This test indicated that there was not a significant difference in P enrichment (*t*(37) = 0.272 = 0.789) at the 95% confidence level between the samples in the depressions (M = 2645.803, S.D. = 504.425) and the 31 samples outside the depressions (M = 2585.594, S.D. = 730.699).

Elements studied in this project were chosen because they generally increase in soil with human occupation intensity **(Homsey and Capo 2006)**. Phosphorus clearly conforms to this pattern, but the covariance of other elements with P is crucial for characterizing activity zones. Regressions between the eight elements identified previously, as well as As, Fe, S and Si were completed in SYSTAT. As and S are included because these elements are associated with historic mining and Fe and Si are included because variations in these elements are related to geologic conditions rather than anthropomorphic. If any of the eight elements identified by Homsey and Capo **(2006)** strongly covary with As, Fe, S, and/or Si, it may suggest that soil enrichment is not a result of prehistoric human activity. **Table 6** summarizes the regression analyses completed for this study, and a p-value table is included in the appendix for reference.

Table 6. *Numbers are* ***Multiple R values*** *determined through linear regression modeling comparing elemental concentration data for various major element combinations* ***(+) or (-)*** *indicate whether the linear relationship between elemental concentrations is positive or negative. Yellow indicates an R^2 value greater than 0.500. Red indicates a p-value greater than 0.200.*

	Ba	Ca	K	Mg
As	0.394 (-)	0.201 .	0.077 .	0.022 .
Ba		0.199 (+)	**0.591 (+)**	0.102 (-)
Ca	0.199 (+)		0.309 (-)	0.287 (+)
Fe	0.429 (-)	0.290 (-)	0.038 (-)	0.043 (+)
K	**0.591 (+)**	0.309 (-)		0.306 (-)
Mg	0.102 (-)	0.287 (+)	0.306 (-)	
Mn	**0.707 (-)**	0.173 (+)	**0.789 (-)**	0.292 (+)
P	**0.784 (+)**	0.308 (+)	0.455 (+)	0.206 (+)
S	0.200 (-)	0.090 (+)	0.419 (-)	0.240 (+)
Si	**0.776 (-)**	0.264 (-)	0.305 (-)	0.269 (-)
Sr	**0.872 (+)**	0.442 (+)	0.237 (+)	0.210 (+)
Zn	**0.623 (-)**	0.184 (+)	**0.571 (-)**	0.235 (+)

	Mn	P	Sr	Zn
As	0.364 (+)	0.311 .	0.362 (-)	0.455 (+)
Ba	**0.707 (-)**	**0.784 (+)**	**0.872 (+)**	**0.623 (-)**
Ca	0.173 (+)	0.308 (+)	0.442 (+)	0.184 (+)
Fe	0.316 (+)	0.374 (-)	0.478 (-)	0.356 (+)
K	**0.789 (-)**	0.455 (+)	0.237 (+)	**0.571 (-)**
Mg	0.292 (+)	0.206 (+)	0.210 (+)	0.235 (+)
Mn		**0.534 (-)**	0.455 (-)	**0.645 (+)**
P	**0.534 (-)**		**0.776 (+)**	0.495 (-)
S	0.377 (+)	0.030 (+)	0.131 (+)	0.211 (+)
Si	0.440 (+)	**0.742 (-)**	**0.874 (-)**	0.332 (+)
Sr	0.455 (-)	**0.776 (+)**		0.389 (-)
Zn	**0.645 (+)**	0.495 (-)	0.389 (-)	

To summarize **Table 6,** the strongest positive and negative elemental concentrations are listed below in **Table 7**.

Table 7. *Strongest positive and negative element correlations. The two related elements are on the left of the T-table, and the Multiple R value quantifying the correlation is to the right.*

Positive Correlations	
Ba; Sr	0.872
Ba; P	0.784
P; Sr	0.776
Mn; Zn	0.645
Ba; K	0.591

Negative Correlations	
Sr; Si	0.874
K; Mn	0.789
Ba; Si	0.776
P; Si	0.742
Ba; Mn	0.707
Ba; Zn	0.623
K; Zn	0.571
Mn; P	0.534

Although three of the anthropogenic elements correlate to Si concentrations, they all have a negative relationship. This suggests that Si and these elements are not geologically related because they would be positively related if this were the case. Regression analyses show that Ba and Sr have the strongest positive relationships to P and that these elements covary as well, so these elements will be explored in greater detail first. Homsey and Capo **(2006)** note that these three elements covary in soils in an Archaic rockshelter site. Friesem et al. **(2016)** analyzed the soil chemistry of a hunter-gatherer rockshelter in India and identified high concentrations of P, Ba, and Sr, like the trend identified in this study. Friesem et al. argue that these covarying concentrations can be attributed to the deposition of organic matter. The same explanation is applicable to the White Creek site, especially because known ecofacts show that site occupants were processing animal remains and this resulted in the deposition of a "…thinly scattered [midden] over the surface of the housepit features" **(Kingsbury and Stoddard 1996)**. Visually, the plots for Sr, Ba, and P are remarkably similar, including the samples containing ash. Again, two-sample, two-tail t-tests were completed to compare the five ashy soils to the 34 non-ashy soils in Microsoft Excel. For Sr, the five samples with ash (M = 191.238, S.D. = 29.14323) compared to the 34 without ash (M = 308.6847059, S.D. = 48.67262) contained significantly lower Sr concentrations, $t(37) = -5.222 = 7.086*10^{-6}$ at the 95% confidence level. For Ba, the five samples with ash (M = 578.426, S.D. = 110.5966) compared to the 34 without ash (M = 745.8474, S.D. = 118.4893) contained significantly lower Ba concentrations, $t(37) = -2.971 = 0.00519$ at the 95% confidence level. Of the three covarying elements, Sr demonstrated the strongest statistical difference between ashy and non-ashy soil samples.

Again, the samples identified above as being within the depressions were compared to those outside the depressions for Sr and Ba with two-sample, two-tail t-tests assuming unequal variance **(Fig. 19)**. For Sr, the eight samples within the depressions (M = 327.99, S.D. = 19.623) compared to the 31 outside the depressions (M = 284.760, S.D. = 65.095) contained significantly higher Sr concentrations, $t(37) = 3.180 = 0.00303$ at the 95% confidence level. For Ba, there was not a significant difference in enrichment ($t(37) = 1.617 = 0.116$) at the 95% confidence level between the samples in the depressions (M = 765.511, S.D. = 55.332) and the 31 samples outside the depressions (M = 713.769, S.D. = 140.945).

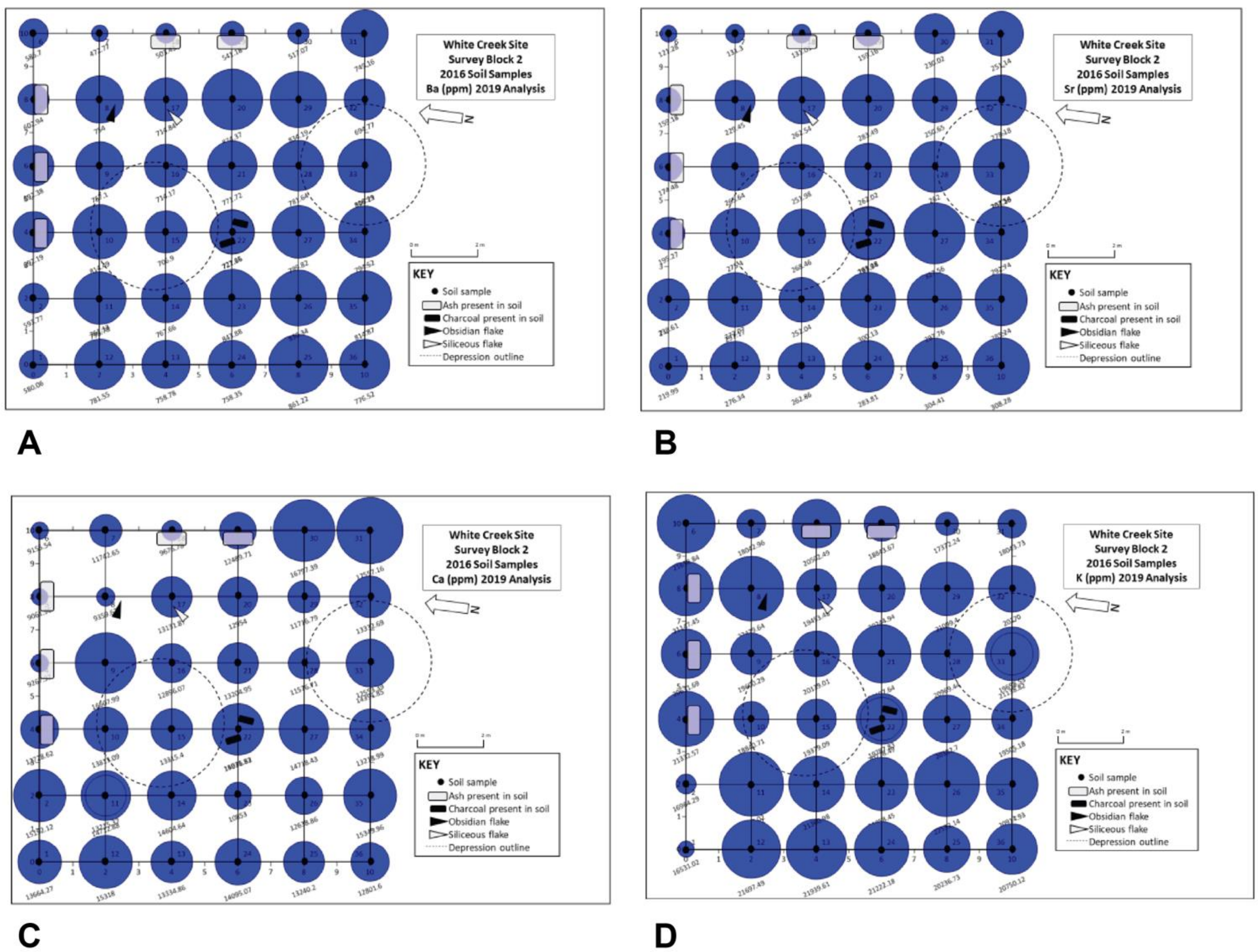


Figure 19. *A – **Ba** concentrations of soil samples from Block 2 detected by HHpXRF; B – **Sr** concentrations of soil samples from Block 2 detected by HHpXRF; C – **Ca** concentrations of soil samples from Block 2 detected by HHpXRF; D – **K** concentrations of soil samples from Block 2 detected by HHpXRF*

Geoarchaeology literature rarely focuses on Ba and typically mentions it as a correlating element to P and/or Sr. Strontium, however, is associated with specific hunter-gatherer activity. Anthropologists have found that Sr-rich diets are based on plants, fish, and nuts (**Homsey and Capo 2006**). The White Creek site is situated on the Middle Fork in a strategic salmon fishing location. Ethnographic studies suggest that salmon fishing was an important seasonal component of the hunter-gatherer economy in prehistory as it was in the historic era. Similarly, root vegetables and pine nuts were gathered in the summer and fall, respectively, in higher elevations by historic populations along the Middle Fork Salmon River. It is possible that prehistoric groups used these resources as well and may have stored dried vegetables and/or nuts at valley campsites for winter use.

Another element is closely associated with diet: Ca is typically elevated in sites where animal butchering was a major activity **(Homsey and Capo 2006, Schuldenrein 1995: 120)**. Five soil samples had particularly elevated Ca concentrations: samples 34, 31, 2, 9, and 30. Sample 34 has a much higher value than the other samples (Ca = 26830.02 ppm). However, this sample location is included within the Trowbridge **(1989)** excavation that uncovered hundreds of "animal bone fragments." Animal bones are the main contributor to Ca in soils, and disturbance from the excavation may be responsible for this anomalously high concentration. The other four samples have a Ca range from 16817.76 ppm to 19378.75 ppm and all are located next to an ashy soil sample and are outside of a depression. A two-sample, two-tail t-test was completed to assess if these four samples are significantly elevated in Ca. The four samples with listed above (M = 17780.11, S.D. = 1177.984) compared to the other 34 samples (excluding sample 34) (M = 13213.51, S.D. = 1806.705) contained significantly higher Ca concentrations, $t(36) = 4.901 = 2.03531*10^{-5}$ at the 95% confidence level. The concentration of Ca in the ashy vs non-ashy soils was also compared: the five samples with ash (M = 11423.64, S.D. = 1784.558) compared to the other 34 samples (M = 14414.461, S.D. = 3029.708) contained significantly lower levels of Ca, $t(37) = -3.141 = 0.0138$ at the 95% confidence level.

Although Ca is more likely than P to mobilize in soil once affixed to clay particles **(Homsey and Capo 2006)**, the spatial distribution of the samples with ash and those around them suggests this is not causing the anomalies in the data. If Ca was becoming concentrated over time due to transportation of soil particles, then one would expect the low points in the depressions or the edge of the terrace near the river to contain elevated Ca levels. Clearly, the ashy soil contains significantly less Ca than the soil near ash-rich areas. This geochemical evidence suggests that prehistoric inhabitants of the site were butchering animals outside of their dwellings and near fire pits, and that this activity was repeated over many years.

Understanding the nature of the fires that created the ashy consistency of the five previously identified soils is important for characterizing prehistoric activity. Homsey and Capo **(2006)** state that ash-dominated hearth features are associated with in-situ, low-temperature wood burning. In their study of an Archaic rockshelter site, they characterize such hearths as having high K concentrations. To test if the same association is present at the White Creek site, a two-sample, two-tail t-test was completed comparing the five ash samples to the 31 others. This test indicated that there was not a significant difference in K enrichment ($t(37) = 0.347 = 0.730$) at the 95% confidence level between the five ashy soil samples (M = 26620.062, S.D. = 1452.484) and the 31 samples without ash (M = 26308.47, S.D. = 1917.869). K spatial variation was assessed in relation to the pit house depressions as well. A two-sample, two-tail t-test assuming unequal variances was performed for K concentrations. For K, there was not a significant difference in enrichment ($t(37) = -1.521 = 0.143$) at the 95% confidence level between the samples in the depressions (M = 25723.96, S.D. = 1056.158) and the 31 samples outside the depressions (M = 26509.57, S.D. = 1987.547).

Because K concentrations do not conform to expected patterns from anthropogenic enrichment, it is more likely that spatial variation is due to geologic/erosional processes. Every sample has a lower concentration of K than the average composition of the alluvial sediment's parent material (see **Table 4**). Feldspars are a dominant mineral in the local granite and were identified in some of the samples as partially eroded crystals. As feldspars are chemically eroded to clay, K^+ ions are released from crystal bonds and either transported in water or remain in the soil to be absorbed by vegetation. This process, rather than the addition of K in soil from wood burning, is the likely cause of the spatial variation of K in the soil sample at the White Creek site.

Like K, it is likely that Mn and Zn spatial variations are due to geologic processes. Zinc and Mn are positively correlated, and these elements are both negatively correlated with K. Potassium is a more felsic element, whereas Zn and Mn are associated with mafic minerals.

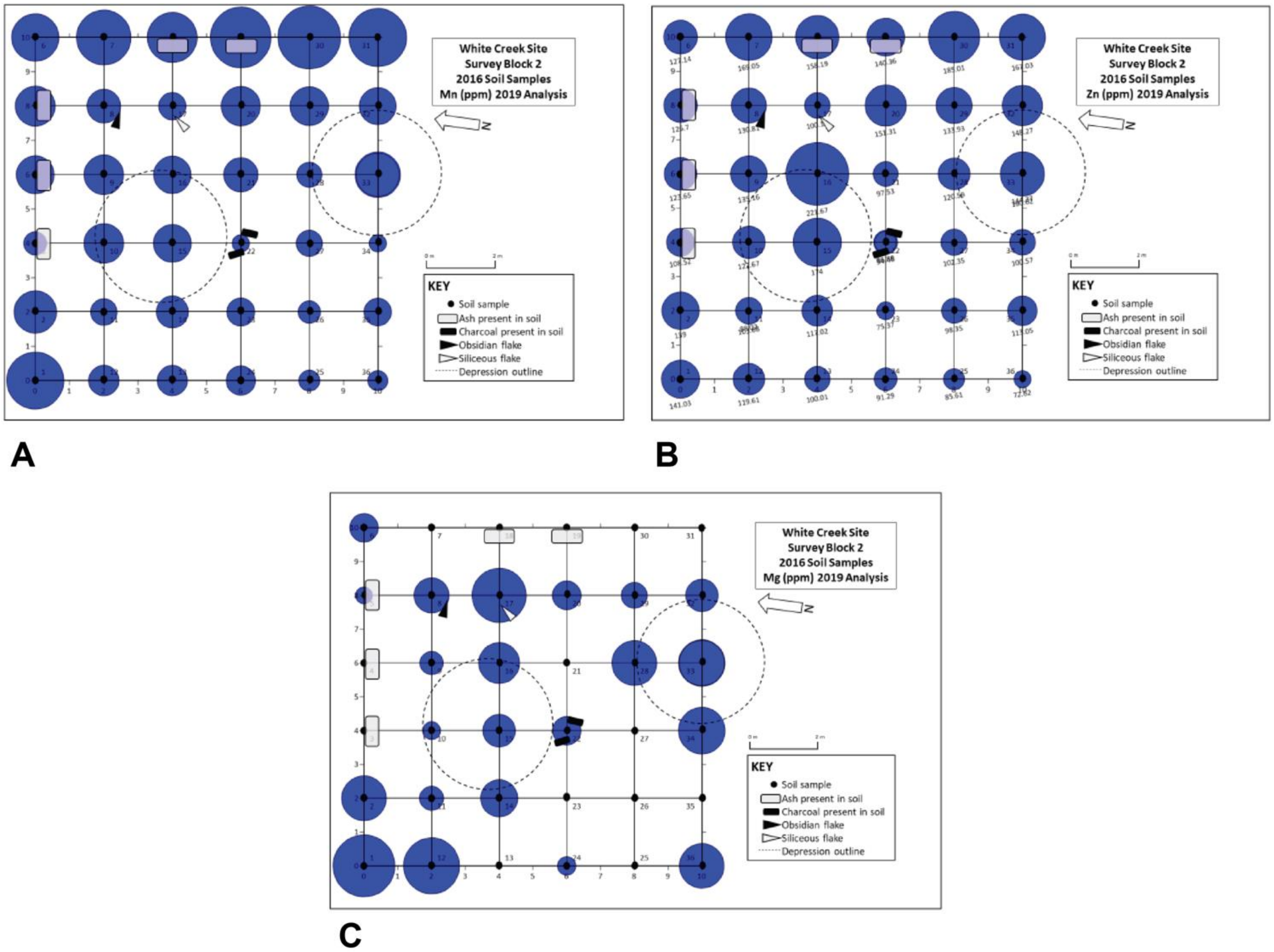


Figure 20. *A – **Mn** concentrations of soil samples from Block 2 detected by HHpXRF; B – **Zn** concentrations of soil samples from Block 2 detected by HHpXRF; C – **Mg** concentrations of soil samples from Block 2 detected by HHpXRF*

Magnesium is included in the eight anthropogenic elements described above, but HHpXRF analysis was unable to detect Mg concentrations in 36% of the samples **(Fig. 20).** Without data collected through the soil extraction method, conclusions about Mg concentration variability cannot be made with confidence.

8. Conclusion

Following the discussion above of the results of magnetic susceptibility and HHpXRF of Block #2 at the White Creek site, it is now possible to return to the original research questions set out at the beginning of the Thesis and discuss what has been achieved.

Research Question 1:

How do concentrations of elements associated with prehistoric anthropogenic activity (namely, Ba, Ca, Mg, Mn, P, K, Sr, and Zn) spatially vary across the 10 m^2 White Creek survey block?

This preliminary research determined that P, Ba, Sr, and Ca strongly covary (see **Table 6**). The most distinct spatial variability in these elements is not associated to the circular depressions; only Sr variability was associated with the pit house depressions according to the two-sample two-tail t-test. However, there was a pattern shared by P, Sr, Ba, and Ca variability comparing ashy and non-ashy soils. The five ash-rich soil samples contained statistically significant low concentrations of P, Sr, Ba, and Ca. These results are summarized in **Table 8** below.

Table 8. *Summary table of two-sample two-tail t-tests comparing select element concentrations in ash/no ash and within/outside depression soil samples. For complete statistics see section 7, above.*

		Soil Characteristic			
		Containing Ash	**No Ash**	**Within Depression**	**Outside Depression**
Relative Concentration	**P**	decreased	increased	-	-
	Sr	decreased	increased	increased	decreased
	Ba	decreased	increased	-	-
	Ca	decreased	increased	-	-
	K	-	-	-	-

Elements K, Mn, Zn, and Mg did not covary with the four above-mentioned elements or with the soil characteristics described in **Table 8**. This may be because the spatial variations of K, Mn, and Zn are associated with geologic and/or natural pedogenic processes rather than anthropogenic ones. The HHpXRF did not detect Mg concentrations in all of the soil samples tested, so it is impossible to draw conclusions about this element without comparable, and hopefully more complete, chemical extraction data for it.

Research Question 2:

Can variability in elemental concentrations be associated with region and period specific anthropogenic activity? Can such variability confidently be associated with prehistoric activity or is it a product of natural geology and soil conditions and/or a product of modern camping activities?

Results from HHpXRF analysis of White Creek soil samples support previous interpretations of prehistoric use of the site. Evidence from ethnographic study, site topography (the presence of 7 to 9 possible pit house depressions), surface surveys, and limited excavations allowed researchers to classify the White Creek site as a late prehistoric winter hunting camp **(Kingsbury and Stoddard 1996, Trowbridge 1989).** Analysis of the ashy vs. non-ashy soil samples collected at the site provided new detail about activity on the terrace. The ashy soils were significantly depleted in four anthropogenic elements (P, Ba, Sr, Ca). Ash-dominated fires burn at temperatures greater than 300°C and convert organic charcoal to inorganic ash **(Braadbaart et al 2017: 1683).** In a study of ash composition using HHpXRF, Braadbaart et al **(2017)** argue that ash samples with low SiO_2/CaO ratios are indicative of wood-fueled fires, whereas high ratios indicate fires fueled with ungulate dung. The average Si/Ca ratio for the five ash samples from the White Creek site is 18.638, but because the soil was sandy throughout Block 2, this ratio is likely impacted by soil composition. The fires that created the ash deposits analyzed in this research were likely fueled by native wood. These five samples were homogeneously composed of ash rich, fine-grained material. This suggests that the ash deposits in these sampled areas is horizontally wide and stratigraphically deep. To produce this volume of ash, fires were likely burned in hearths at this location over several years, possibly decades. The lack of evidence of modern campfires at this point and the extent of the ash deposit strongly suggests that a prehistoric, seasonal hearth was used outside of the house pit depressions at this site.

HHpXRF evidence may indicate what this hearth was used for as well. The area directly between the ashy soil and the house pit depressions is significantly elevated in Ca. In geoarchaeology, Ca is associated with animal butchering because bone is elevated in Ca. The limited Trowbridge **(1989)** excavations produced hundreds of ungulate bone fragments likely associated with prehistoric use. The association of butchered ungulate bone fragments with the site and the spatial variation between the ash-enriched soils and the depressions suggests that prehistoric peoples butchered and prepared mountain sheep or other ungulates in this area of the site.

The results of HHpXRF analysis of Ca in White Creek soils is promising and strongly suggests that particular areas were used for processing and cooking ungulates. Artifacts from the site confirm that the terrace was occupied during the late prehistoric period and the Ca variation results add support to past research. However, without large-scale excavation, it is impossible to rely on geochemical interpretations because of the potential of modern contamination of soil chemistry. In modern times, the White Creek site has been used seasonally by campers and rafters in the Middle Fork Valley. According to NFS surveyors, modern campers occasionally tent on the site and reports of digging within the depressions are recorded (see **Fig. 21**). **(Kingsbury and Stoddard 1996)**. The Trowbridge **(1989)** excavation reported stratigraphic disturbance of the two depressions excavated.

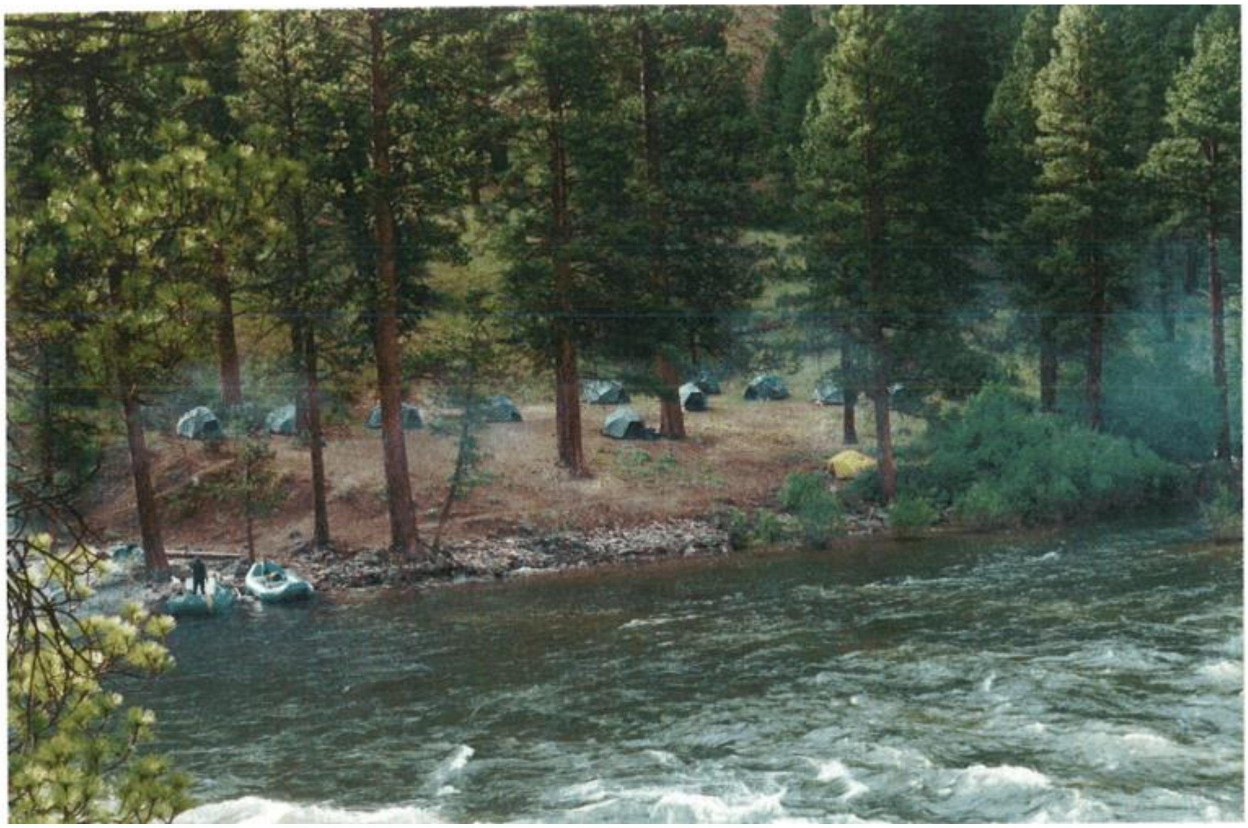


Figure 21. *"River runners tenting on the White Creek housepit village prehistoric site on the morning of June 26, 1996" (from Kingsbury and Stoddard 1996).*

Because of modern use and erosion processes at the site, one would expect the soil chemistry within the depressions to be inconsistent with the other samples. Because the depressions are topographic low points, erosion should concentrate material within the depressions, causing them to act as traps for the anthropogenically altered soil. Modern disruption of the depressions would likely affect their soil chemistry as well. This study found that anthropogenic element variation within the depressions was not significant compared to the rest of the soil samples. If erosion significantly impacted the spatial variation of soil elemental concentration, then the depressions would be elevated in the elements discussed in this BPhil Thesis. This is clearly not the case: erosion does not affect soil chemistry variation as one might expect. The results of this research lend support for the use of HHpXRF at prehistoric sites, even if they are impacted by modern activity.

Research Question 3:

Can HHpXRF and soil extraction methods produce comparative results?

As stated above, the results from the soil extraction analysis is unavailable as of the submission of this BPhil Thesis. The author intends to compare the HHpXRF and soil extraction results when they become available. It is likely that the two methods will produce similar spatial variability trends in the key elements identified above, but there may be some samples that produce radically different results. This is because the HHpXRF results are dependent on the composition of the thin layer of soil exposed at the membrane of the sample cup, whereas the soil extraction results dissolve all particles subjected to this analysis.

These results also contribute to the broader research goals of the MFGRP and the NFS. Incorporating geochemical analysis as an archaeological research technique directly complies with the FC-RONRW Historic Preservation Plan developed to manage cultural resources in the region **(SCNF 2016: 34)**. This work builds on the extensive geophysical research completed at Middle Fork sites by the MFGRP from 2014 to 2018. By including geochemical research methods in a research design that already utilizes several analysis techniques, the summed results of the MFGRP's research are stronger than the value of any individual method. The results of the pilot geochemical research reported in this BPhil Thesis are compelling alone, but when combined with the total sum of data recorded with geoarchaeological techniques, they lend further support for the viability and reliability of minimally invasive archaeological research methods in the Middle Fork.

9. Future Directions

The most important next step for this research is the interpretation of the soil extraction results. The combination of HHpXRF and soil extraction research will be the most in-depth geochemical study of a prehistoric site in the Middle Fork Valley conducted thus far. This interpretation will also suggest the viability of HHpXRF as a tool for minimally invasive scientific investigation in the region. Soil extraction research is both time-consuming and expensive and requires specialized knowledge and access to lab equipment. HHpXRF, however, is a rapid and easy-to-use tool for assessing elemental variation. Other researchers have compared the results of the two methods **(Lubos et al. 2016, Frahm et al. 2016, Oonk et al. 2008, Frahm and Doonan 2013)**, but soil composition and occupation intensity are important factors that highly affect the viability of HHpXRF as a reliable field/lab instrument.

If the results of this research show that HHpXRF is reliable compared to soil extraction methods, then there will be further encouragement for the NFS to adopt this technology into regular site management projects. The preliminary results presented in this BPhil Thesis indicate that HHpXRF is valuable for identifying activity zones associated with prehistoric activity when topographical features like depressions and artifact distributions are known. Between the work done by the MFGRP and past subsurface investigations in the Middle Fork Valley, there are a number of sites that would be candidates for similar HHpXRF investigations. Many of these sites have already been extensively researched and are identified as "particularly at risk," including Camas Creek, Grassy II, Hospital Bar, Indian Creek, Lower Jackass, Rock Island, Sheepeater, Stoddard Creek, and Woolard Creek **(SCNF 2016: 34).** Expanding on scientific investigations that conform to minimally invasive standards should be an important management strategy in the FC-RONRW moving forward. Based on this research, the incorporation of geochemical techniques, particularly HHpXRF, in such investigations allows researchers to reveal unexpected details of prehistoric life that are undetectable from the surface.

Appendix

Figure 7. Geologic Map Units

CZs Windermere Supergroup (Cambrian to Neoproterozoic) – Upper part consists of shallow marine and fluvial quartzose sandstone, and minor siltite, shale, and limestone of the Brigham Group of southeast Idaho, Wilbert Formation of east-central Idaho, and quartzites of unknown affinity west of Borah Peak. More highly metamorphosed equivalents are quartzite, metaconglomerate, metasiltite, calc-silicate marble, and schist of Gospel Peak successions in central Idaho; mature quartzite, biotite schist, and minor calc-silicate rocks of Syringa metamorphic sequence east of Moscow; and schist and quartzite in the Albion Range (Elba Quartzite, schist of Upper Narrows, quartzite of Yost, schist of Stevens Spring, quartzite of Clarks Basin, schist of Mahogany Peaks, and Harrison Summit Quartzite). Lower part consists of diamictite, immature sandstone, and bimodal volcanic rocks related to continental rifting. Includes Pocatello Formation (700-665 Ma), formation of Leaton Gulch near Challis, Shedroof Conglomerate in extreme northwest Idaho, and metamorphic equivalents (schist, marble, calc-silicate rocks, metaconglomerate, and ~686 Ma metavolcanic rocks) of Gospel Peaks successions in central Idaho.

Kg Granodiorite and two-mica granite (Cretaceous) – Granodiorite and granite containing biotite, commonly with muscovite; includes bulk of Atlanta lobe (85-67 Ma) and isolated plutons in northern Idaho (107-67 Ma).

Ktg Tonalite, granodiorite and quartz diorite (Cretaceous) – Tonalite, granodiorite, and quartz diorite, typically hornblende-bearing; including the Payette River tonalite (~90 Ma) along western border zone of the Atlanta lobe, and ~99 Ma Croesus pyroxene-biotite quartz diorite south of Hailey. Also includes granodiorite with potassium feldspar megacrysts that is typically hornblende-bearing and foliated (~90 Ma in central Idaho and ~100 Ma in northernmost Idaho) and early mafic phases of the Bitterroot lobe (~70Ma).

OCi Syenitic intrusive rocks (Ordovician and Cambrian) – Syenite, quartz syenite, alkali-feldspar granite, and subordinate gabbro (500-485 Ma). Includes Beaverhead, Arnett Creek, Deep Creek, and Yellowjacket plutons southeast and west of Salmon.

PzYs Metasedimentary rocks (Paleozoic to Mesoproterozoic) – Quartzite, feldspathic quartzite, calc-silicate gneiss, biotite gneiss, schist, and amphibolite north and east of McCall and as pendants in the southern part of the Idaho batholith; schist, quartzite, and marble in southwestern Idaho; argillite, siltite, quartzite, carbonate-bearing quartzite, dolomite, phyllite, and conglomerate of the Deer Trail Group in northwest corner of state; and quartzite, Hayden Creek diamictite, and siltite stratigraphically above (?) the Swauger Formation south of Salmon.

Qa Alluvial Deposits (Quaternary) – Deposits in valleys consisting of gravel, sand, and silt. Includes younger terrace deposits. May contain some glacial deposits and colluvium in uplands.

Tcv Challis Volcanic Group (Eocene) – Dacite, andesite, and rhyolite tuffs and lfows and subordinate basalt and latite flows; covers large area in south-central Idaho. Includes Absaroka Volcanic Group near Henrys Lake and scattered volcanic rocks in eastern and northern Idaho.

Tei Challis intrusive rocks (Eocene) – Shallow roots of Challis volcanic field. Older suite of granodiorite and quartz monzodiorite and subordinate diorite, granite, and subvolcanic dacite; includes Jackson Peak, Beaver Creek, Marsh Creek, and Summit Creek stocks (49-45 Ma). Younger suite of granite and minor syenite and subvolcanic rhyolite; includes Sawtooth, Casto, Bungalow, and Lolo Hot Springs plutons (47-43 Ma).

Yha Hoodoo Quartzite and argillaceous quartzite (Mesoproterozoic) – Feldspathic fine-grained quartzite in central Idaho that is stratigraphically above the Yellowjacket Formation. Also includes argillaceous quartzite above the Hoodoo Quartzite.

Yy Yellowjacket Formation (Mesoproterozoic) – Siltite, calc-silicate rocks, argillite, and rare marble in central Idaho, stratigraphically below the Hoodoo Quartzite.

White Creek Block 2 Soil Sample Characteristics

Sample	Munsell Color	Composition	Grain Size	Charcoal	Ash
1	10YR 4/2	silt	silt	N	N
2	10YR 5/2	silt loam	silt to fine sand	N	N
3	10YR 5/2	silt	silt	N	Y
4	10YR 5/2	silt	silt	N	Y
5	2.5Y 5/3	silt	silt	N	Y
6	10YR 5/3	silt	silt	N	N
7	10YR 4/2	silt	silt	N	N
8	2.5Y 5/3	silt	silt to very fine sand	N	N
9	10YR 4/2	silt loam	very fine sand to fine sand	N	N
10	10YR 4/2	silt loam	very fine sand to fine sand	N	N
11	10YR 4/2	sandy loam	fine sand	N	N
12	10YR 4/2	sandy loam	very fine sand to fine sand	N	N
13	10YR 4/2	silt loam	very fine sand	N	N
14	10YR 4/2	silt loam	very fine sand	N	N
15	10YR 4/2	sandy loam	fine sand	N	N
16	2.5Y 4/2	silt loam	very fine sand to fine sand	N	N
17	10YR 4/2	sandy loam	very fine sand to fine sand	N	N
18	2.5Y 5/3	silt	silt	N	Y
19	10YR 4/2	silt	silt	N	Y
20	10YR 4/2	sandy loam	very fine sand to fine sand	N	N
21	10YR 4/2	silt loam	silt to very fine sand	N	N
22	10YR 4/2	silt loam	silt to very fine sand	Y	N
23	10YR 4/3	sandy loam	very fine sand to fine sand	N	N
24	2.5Y 4/2	sandy loam	very fine sand to fine sand	N	N
25	10YR 4/2	loamy sand	fine sand	N	N
26	10YR 4/2	loamy sand	fine sand	N	N
27	10YR 3/3	sandy loam	very fine sand to fine sand	N	N
28	10YR 4/2	sandy loam	very fine sand to fine sand	N	N
29	10YR 4/2	silt loam	silt to very fine sand	N	N
30	10YR 3/1	silt	silt	N	N
31	10YR 4/2	silt loam	silt to very fine sand	N	N
32	10YR 4/2	sandy loam	very fine sand to fine sand	N	N
33	10YR 4/2	sandy loam	fine sand	N	N
34	10YR 4/2	sandy loam	fine sand	N	N
35	10YR 4/2	sandy loam	fine sand	N	N
36	10YR 4/2	sandy loam	very fine sand to fine sand	N	N

Sample	Notes
1	subrounded
2	subrounded
3	homogeneous composition, extremely airy texture, dull ashy color
4	homogeneous composition, possibly ash? Not as much as #3
5	homogeneous composition, extremely airy texture, dull ashy color
6	slightly less homogenous than #5
7	
8	increasing sand content
9	
10	
11	
12	
13	
14	
15	less homogenous, more loose plant material included in sample
16	
17	heterogenous compostion with a few coarse grains including a 3mm long angular silica(?) glass flake
18	homogenous composition, extremely airy texture
19	homogenous composition, not as airy texture as #18
20	
21	homogenous composition
22	
23	homogenous composition
24	subrounded quartz, generally increasing grain size
25	subangular to subrounded
26	subrounded, mica flakes and K-feldspar grains
27	mica flakes and K-feldspar grains
28	subrounded
29	
30	very homogenous compositon
31	much less homogenous than #30
32	subrounded
33	subrounded
34	subrounded, very homogenous composition
35	subrounded, less homogenous than #34
36	subrounded

White Creek Block 2 HHpXRF data available as Excel spreadsheet.

White Creek Block 2 subsurface magnetic susceptibility data available as Excel spreadsheet.

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