THESIS

CHRONOLOGY, SPATIAL ORGANIZATION, AND MOBILITY AT FLATTOP BUTTE (5LO34), A PREHISTORIC LITHIC QUARRY IN THE CENTRAL PLAINS OF NORTH AMERICA

Submitted by
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ABSTRACT

CHRONOLOGY, SPATIAL ORGANIZATION, AND MOBILITY AT FLATTOP BUTTE (5LO34), A PREHISTORIC LITHIC QUARRY IN THE CENTRAL PLAINS OF NORTH AMERICA

This thesis reports on the results of an archaeological investigation at Flattop Butte (5LO34), a prehistoric lithic quarry located in northeastern Colorado. The site is an important location in the prehistory of the Central Plains of North America because it is the source of Flattop chalcedony, a cryptocrystalline tool stone used by ancient peoples for over 13,000 years, since the time that humans first entered the region. Sources of high-quality tool stone are uncommon, and separated by vast distances, in the Central Plains. This fact made Flattop Butte an essential destination for ancient, Indigenous Native American groups operating in the region, who visited it again and again for millennia, each time leaving evidence of their presence.

Despite this importance, Flattop Butte has been the subject of only cursory archaeological investigation prior to the work reported here. Indeed, the vast majority of what is known about Flattop Butte comes not from the site itself, but rather from distant locations where Flattop chalcedony is found in the archaeological assemblages of ancient groups who used this lithic material for tool making. This thesis then represents an attempt to begin to lift the veil on Flattop Butte, and to explore it as an important archaeological site in its own right. It is a place that has much to say about the ancient peoples of the Central Plains, but only if some sense can be made of the seemingly incomprehensible mass of intermixed cultural materials and byproducts that were deposited on its surface and in its depths over hundreds of generations.

With this goal in mind, the archaeological investigation reported here was designed to gather evidence at Flattop Butte relevant to three foundational research questions. The first is the chronology of use of the site, i.e., when was Flattop Butte used as a lithic source, and when were particular locations at the site used for these purposes? The second research question relates to spatial organization, i.e., where at the site did ancient groups carry out their lithic procurement activities, and did they segregate this work into separate, specialized activity areas? The final question relates to the effect, if any, that quarrying tool stone at Flattop Butte had on the mobility patterns of the ancient groups that visited the site for this purpose. Specifically, were these groups engaged in "embedded" procurement incidental to their subsistence rounds, having little impact on their overall mobility patterns, or were they engaged in "direct" procurement, making special trips to the site having significant impacts on their mobility patterns? Evidence relevant to these questions was gathered at Flattop Butte through survey and excavation. In addition, a literature review of the offsite use of Flattop chalcedony through time was conducted. The results of these efforts are reported here.

On the question of chronology, it was found that Flattop Butte was continuously exploited as a lithic source in all prehistoric periods, for over 13,000 years. In addition, specific locations were identified at the site with evidence suggesting identifiable activities taking place at particular times, including a possible Paleoindian period secondary reduction workshop, two possible Archaic period workshops, and a Late Prehistoric period quarry pit. On the question of spatial organization, evidence was gathered suggesting that at various times ancient peoples organized their production of lithic materials at Flattop Butte into distinct task locations – quarry pit areas, secondary reduction workshops, and habitations – that were placed at a distance from each other on the butte. Finally, on the question of mobility, evidence suggests a high level of both logistical

organization and labor investment in lithic production at Flattop Butte, as well as frequent long-distance transport of Flattop chalcedony, indicating that some of the groups that acquired Flattop chalcedony at the site were engaged in special-purpose “direct” procurement, around which their mobility patterns had to be arranged.

ACKNOWLEDGEMENTS

The archaeological investigation reported here could not have gone forward or been completed without the work, contributions, and participation of so many others. First among these is my graduate advisor, Dr. Jason LaBelle. Dr. LaBelle welcomed me into the community of Rocky Mountain and Great Plains archaeologists and encouraged me to consider Flattop Butte (among countless other options) as the subject of this thesis. Dr. LaBelle has made it one of his many priorities to shed light on the archaeology of northeastern Colorado. In pursuit of that goal, he has cultivated not only a deep understanding of the region and its ancient past, but also a deep connection with the community and its many archaeological professionals, supporters, enthusiasts, and avocationalists. This project was built on these foundations and could not have been accomplished without them. Dr. LaBelle will always have my thanks for his support, encouragement, guidance, and friendship.

Equally essential to the successful completion of this project, was Dr. LaBelle's research lab, the Center for Mountain and Plains Archaeology. For nearly two decades, Dr. LaBelle has assembled talented and motivated students from across the country, and marshalled equipment, facilities and financial resources to support them, creating a dynamic, stimulating, and productive environment, and a close-knit community, dedicated to the pursuit of knowledge and the advancement of the profession. This project drew on all of the resources of the CMPA, including funding from the Jim and Audrey Benedict Endowment for Mountain Archaeology for crew compensation. The people of the CMPA were also a valuable resource in the execution of this project. Specifically, I wish to thank Kelton Meyer for his participation in early reconnaissance at the site, and for his insights and ideas about how to investigate a sprawling, complex, palimpsest. I also wish to thank CMPA students Aleah Kuhr and Kelsy Kreikemeier, who not only participated

in early testing of the survey design employed at the site, but also were an essential part of the crew that carried out the work reported on here. Finally, I wish to thank Sebastian Schipman and Leah Burke who rounded out the CMPA Flattop Butte crew and contributed much hard work and good cheer to the effort.

As important and essential as Dr. LaBelle and the CMPA were to the completion of this project, it could not have gone forward, or been carried out in the way that it was, without the participation and support of a number of local community members who make their homes or do business in northeastern Colorado, where Flattop Butte is located. First among these is Mike Toft, of Sterling, Colorado, who has devoted a lifetime to investigating, preserving, and understanding the archaeological record of the region. Mike has been a fixture on the northeastern Colorado archaeological scene for decades. He is responsible for identifying many (likely most) of the archaeological sites in the region, he has co-authored numerous papers on the topic, and he has been closely involved in instigating and participating in many of the most important archaeological investigations in the region, including the Donovan and Jones-Miller sites. Mike's contributions to this project are so numerous and significant that it is impossible to document them all, or overstate their importance. He shared his knowledge of Flattop Butte, gained from decades of exploring it and the surrounding areas. He shared his home, making it a base of operations for this project. He contributed his labor, spending countless hours in the survey and excavation work reported here. Perhaps most importantly he shared his wisdom, his curiosity, and his friendship, making him an essential partner in the fieldwork carried out here.

In addition to Mike Toft, two other Sterling, Colorado residents also played important parts in this project, and both deserve acknowledgement here. The first is Mike Dollard, Mike Toft's long-time companion in the exploration of the archaeology of the region. For decades, the "two

Mikes" wandered together over vast prairies, steep bluffs, and back roads searching for signs of ancient human presence. Mike Dollard was an early and ardent supporter of this project, sharing his knowledge of the site, offering advice for overcoming its many challenges, and perhaps most importantly connecting the author with his vast network of local friends and colleagues, built over decades through his warmth, irascible charm, and good nature. Tragically, Mike Dollard fell ill just before the project here was begun, and passed away shortly after it was completed. He is greatly missed by everyone who had the privilege of knowing him. In addition to Mike Dollard, thanks are owed to another Sterling resident, Grant Otzenberger, former head of the local historical society and an experienced avocational archaeologist. From the first day of fieldwork, Grant was a constant participant, contributing countless hours of labor in the survey and excavation work conducted here. His skills, good nature, and boundless energy powered this project.

Thanks and acknowledgement are also owed to the landowners who gave permission for this project to take place. The majority of Flattop Butte is owned by Sunset Land & Cattle LLC. Without the gracious support and permission of its owner and managing member, Jeff Timmerman, and its ranch manager, Dale Sutter, Flattop Butte would have remained shrouded in mystery. They are greatly thanked for allowing the work carried out here to go forward. Thanks are also owed to the Colorado State Land Board, the owner of northernmost portion of the butte, who granted permission for survey on their property.

A number of other individuals contributed to this project in important ways. Sarah Carlson, the curator of collections for the anthropology department at the University of Denver, provided access to field notes of E. B. Renaud's pioneering work in northeastern Colorado as well as photographs of Renaud's collection at Flattop Butte. Geologist Ned Sterne visited the site with the author and provided valuable insights into geologic stratigraphy and formation of the butte. Joshua

Reyling of the Colorado State University Geospatial Centroid use data generated in the fieldwork conducted here to prepare the inverse distance weighting maps included here to depict debris and color distributions.

Numerous other organizations also provided key support for this project through generous grants of financial assistance. The Karen S. Greiner Endowment, a fund administered by the CSU Department of Anthropology and Geography, donated funds to purchase much-needed snake gaiters to protect the field crew from the many rattlesnakes who make their homes on Flattop Butte. Additional support was provided by the Ward F. Weakly Memorial Fund administered by the Colorado Council of Professional Archaeologists, and by the Dorothy Mountain Memorial Graduate Scholarship of the Loveland Archaeological Society, both of which contributed funds for radiocarbon dating of bone samples recovered in the excavation unit.

Finally, thanks are given to Dr. Mary Van Buren, CSU professor of anthropology, and Dr. Jared Orsi, CSU professor of history, for their kind agreement to act as members of my thesis committee, and readers of this report. I had the privilege of attending two graduate seminars with Dr. Van Buren, and her knowledge, thoughtfulness, and guidance greatly enhanced my development as an archaeologist. I also had the privilege of attending Dr. Orsi's graduate history writing seminar, where I learned more about the craft of writing than at any other time in my long career.

DEDICATION

This thesis is dedicated to my wife, D’arcy Madden, whose love, support, encouragement, and patience formed the essential and unwavering foundation of this project. I also dedicate this thesis to my father, Thomas Madden, who kindled a love of the past in me with his dinner-table tales of the ancient world.

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CHAPTER 1: INTRODUCTION

Flattop Butte is a 57 hectare, Oligocene-age, erosional remnant of the White River Group formation, that rises 38 meters above the shortgrass prairie of northeastern Colorado (Figure 1). It is a location that is well-known to archaeologists working in the Central Plains of North America.

Figure 1. Flattop Butte, viewed from the southeast, August 2023 (photograph by the author).

This is so because Flattop Butte is the source of Flattop chalcedony (Figure 2), a highly prized cryptocrystalline toolstone used by ancient, Indigenous North American groups in the region throughout prehistory. High-quality toolstone sources are uncommon in the Central Plains, and are separated by "vast areas where little to no lithic material is available" (Holen 2014:182).

Figure 2. Flattop chalcedony, bedded in limestone (photograph by the author).

Because of this scarcity, for at least 13,000 years, Flattop Butte served as an anchoring point on the prehistoric landscape. It was a crossroads and a Central organizing location, where human groups operating in the Central Plains returned again and again to obtain essential lithic raw materials, and left evidence of their presence and raw material acquisition activities over millennia. Indeed, lithic sources such as Flattop Butte are among the first locations that humans entering a new region would be expected to seek out (Purdy 1984). Thus, evidence of the entire span of human occupation in the Central Plains is likely present at Flattop Butte.

Despite its importance, Flattop Butte has been the subject of almost no systematic archaeological investigation. This is no doubt due to the size and seemingly insurmountable complexity of its assemblage. Over thousands of years of continuous use, enormous quantities of cultural materials and byproducts have accumulated on the surface of Flattop Butte, and been deposited in its depths, creating a massive, chaotic, often intermixed, archaeological record. As a result, this daunting record has been mostly passed over by archaeologists, no doubt because of the "'psychic numbing' which occurs whenever we are faced with the seemingly insurmountable task of quarry investigations" (Greiser 1983:13).

What is known about Flattop Butte, because of the frequent appearances of Flattop chalcedony in far-flung archaeological assemblages, is when, where, and how lithics procured from the butte were used *off-site* by ancient groups. What is not known about Flattop Butte is anything about when, where, and how this material was procured *on-site*, at its source. In this way, Flattop Butte is a site that everyone knows, but no one knows anything about. This thesis then is an attempt to nudge Flattop Butte out of its obscurity.

Specifically, this thesis and the field work on which it reports seek to shed light on three Central research questions. The first is concerned with the chronology of use of the site. It asks:

(i) When was Flattop Butte used as a lithic source? and (ii) When were particular areas of the site employed for the production of lithic raw materials? The second research question is concerned with spatial organization at the site. It asks: (i) Where at Flattop Butte did prehistoric groups carry out their raw material procurement activities? and (ii) Did they organize these activities in separate, specialized locations such as lithic extraction areas, secondary reduction workshops, and habitations? The third and final research question relates to the question of how quarrying at Flattop Butte affected the mobility patterns of the groups who acquired lithics there over time. It asks: (i) How logistically organized were the production activities of these groups at the site? (ii) How much labor and time did they invest to extract and process tool stone at the site? and (iii) How did these factors influence their choices about whether to engage in low-cost, low-volume, "embedded" procurement of Flattop chalcedony, having little impact on mobility patterns, or high-cost, high-volume, "direct" procurement, having a significant effect on mobility (Binford 1979:259).

Evidence relevant to these questions was sought at Flattop Butte through a combination of survey and excavation. Specifically, crews performed: (i) a walking survey of the surface of the butte, (ii) measurement and analysis of lithic reduction debris in selected high-density debris areas, (iii) mapping of quarry pits, and (iv) excavation of an aboriginal quarry pit. In addition, a literature review was performed of published reports of lithic materials from Flattop Butte appearing in dated archaeological contexts. The evidence produced by this investigation, and what it says about when, where, and how lithic raw materials were produced at Flattop Butte, are presented hereafter, organized into six parts.

First, in Chapter Two, context is provided for the present investigation through a discussion of: (i) the physical characteristics, geography, and geology of Flattop Butte, (ii) the mineralogical and visual characteristics of Flattop chalcedony, and (iii) the brief history of past archaeological investigations at the site. Next, in Chapters Three and Four, the goals pursued, methods employed, and results obtained in the survey and excavation project conducted at Flattop Butte are discussed. Then, in Chapters Five, Six, and Seven, the ways in which the evidence produced by this investigation shed light on the questions of chronology, spatial organization, and mobility are considered. Finally, in Chapter Eight, an overview of the investigation and its findings is provided, together with suggestions for future work at Flattop Butte that build on the progress made here.[1]

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[1] Collections made in connection with the archaeological investigation reported here are housed in the Archaeological Repository of Colorado State University (AR-CSU). Detailed location data for the artifacts and features discussed in this report are maintained in the sensitive records files of the Center for Mountain and Plains Archaeology at Colorado State University.

CHAPTER 2 – CONTEXT OF STUDY

Physical Description and Location of Flattop Butte

Flattop Butte (5LO34[2]) is a low, irregularly shaped mesa in the far northeast corner of Colorado (Figure 3). It is 13.5 km south of the Nebraska border, and 30 km northwest of the South Platte River and the city of Sterling, Colorado.

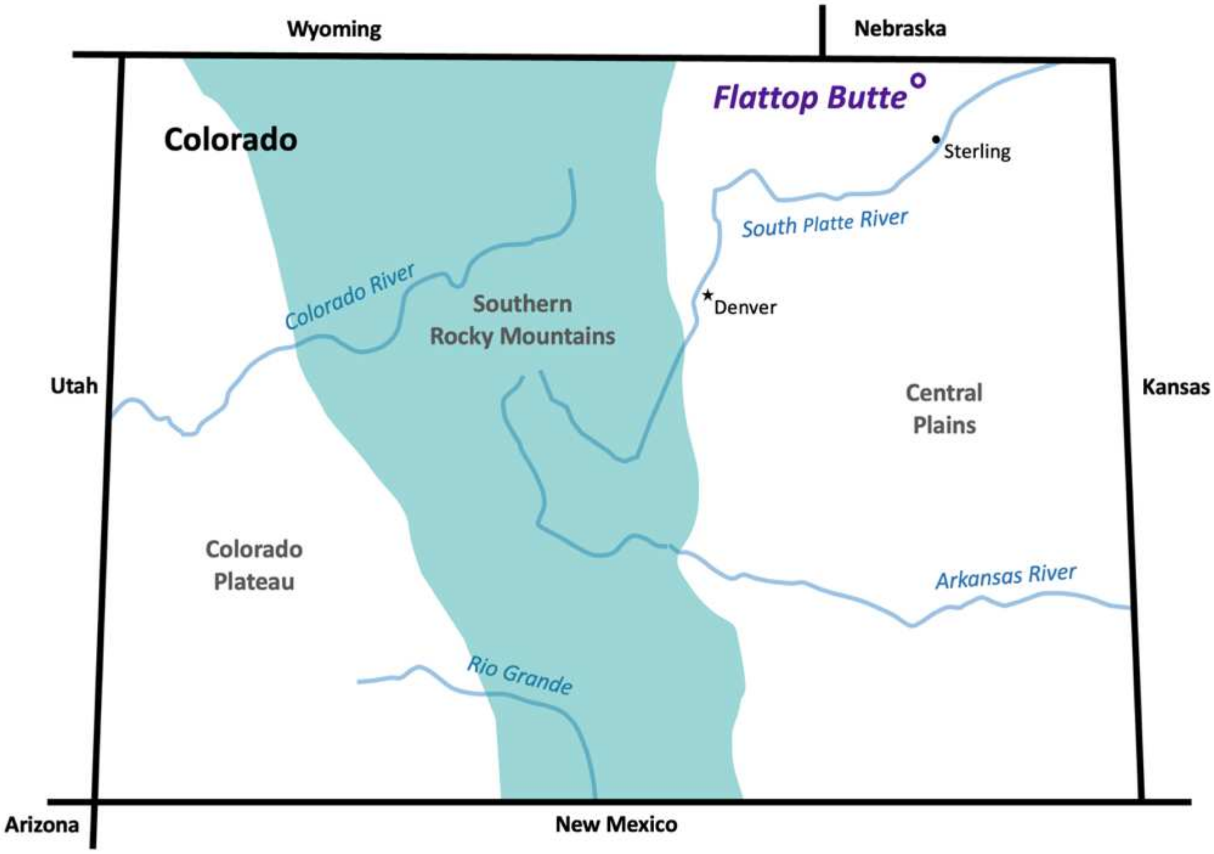

Figure 3. Map of Colorado showing location of Flattop Butte.

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[2] Flattop Butte has been assigned the unique identifier “5LO34” under the Smithsonian Institution Trinomial System (SITS). However, over the last 75 years, it has been referred to at various times and places using other SITS designations including 5LO1, 5LO12, 5LO473, and 5LG121. The history and derivations of these other designations are discussed in more detail in Appendix A.

The surface of the butte rises an average of 38 meters above the surrounding treeless, semi-arid, shortgrass prairie. It covers 57 hectares, and (as the name implies) is flat, with a slight depression in the center (Figure 4) (United State Geological Survey [USGS] 2016). The butte-top is surrounded by a downward sloping apron of eroded talus, extending approximately 100 meters on all sides (Figure 4). The closest reliable source of water are the springs that feed nearby Darby Creek, approximately 2 kilometers east of the butte (USGS 2022).

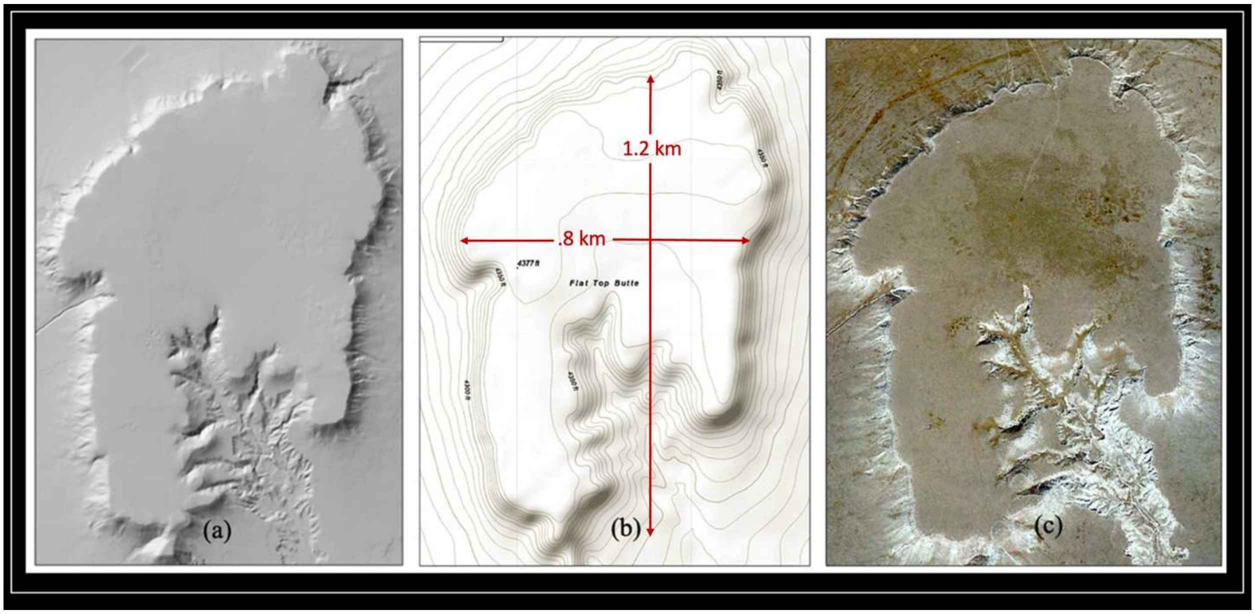

Figure 4. LiDAR, topographic, and aerial views of Flattop Butte.
From Colorado Water Conservation Board (2019); Google Earth Pro (2024).

Geology of Flattop Butte

Regional Geology

Flattop Butte is located in the northeastern portion of the Colorado Piedmont section of the Great Plains (Figure 5) (Madole 1991). The Piedmont is an erosional inlier that has been mostly stripped by the South Platte River and its tributaries of the Miocene fluvial rocks (the Ogallala Formation) that cover most of the adjoining High Plains (Madole 1991).

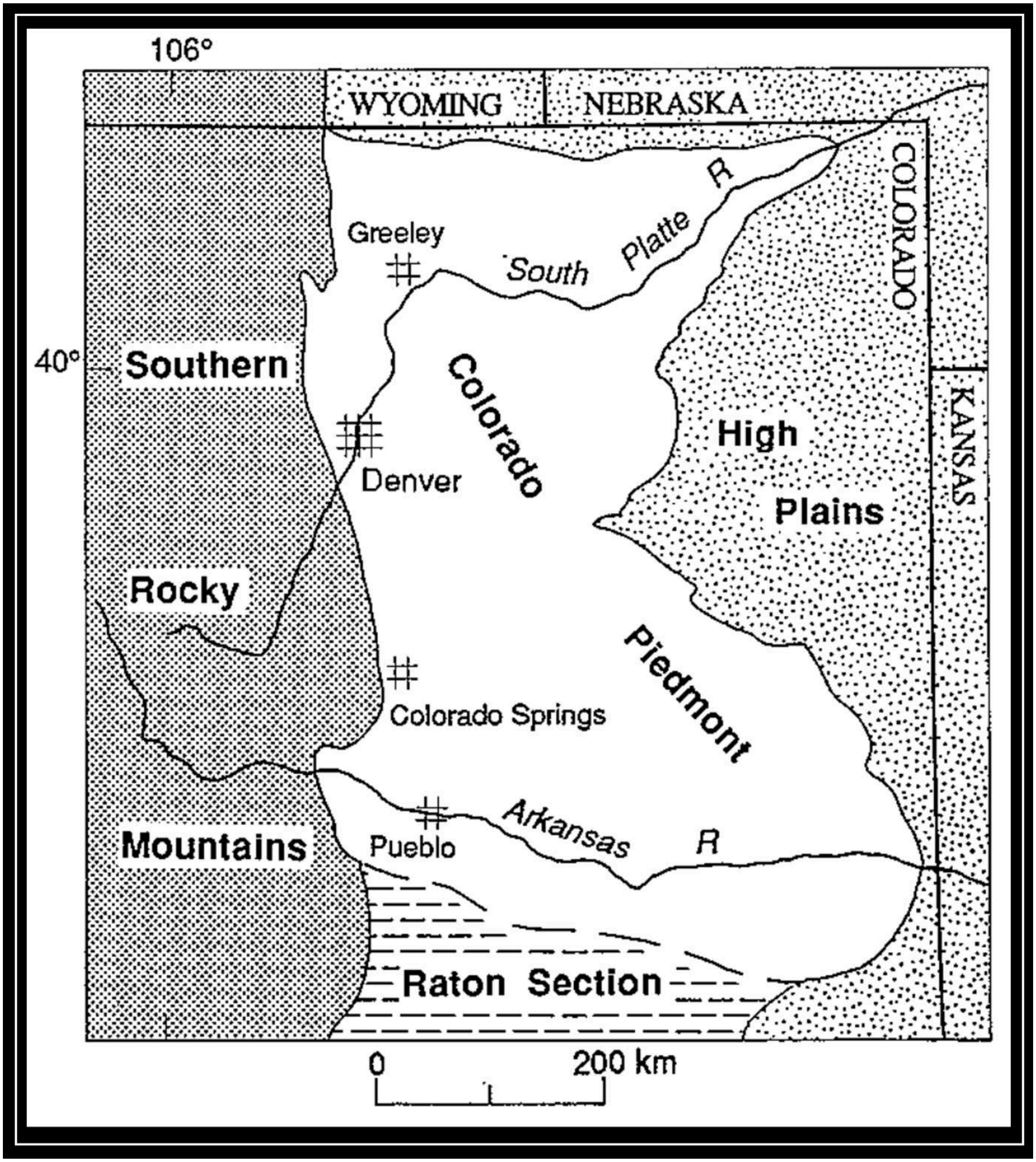

Figure 5. Map of the Colorado Piedmont and surrounding physiographic subdivisions. From Madole (1991).

Flattop Butte is one of several small, high landmarks in northeastern Colorado, including Pawnee Buttes, Fremont Butte, Twin Buttes, and Kirchnavy Butte, that are erosional remnants of tertiary formations, isolated remnants of which can also be found in western South Dakota, Montana, Wyoming, North Dakota, and Nebraska (Figure 5) (Ahler 1977; Boen et al. 2021; Carlson and Peacock 1975; Galbreath 1953:54; Hoard, et al. 1992; Ives 1984; Scott 1982). The White River Group exposure in northeastern Colorado where Flattop Butte is located is rich in fossil mammals, making it the source of repeated collection since 1870 by, among others, the American Museum of Natural History (Galbreath 1953; Prothero 1996).

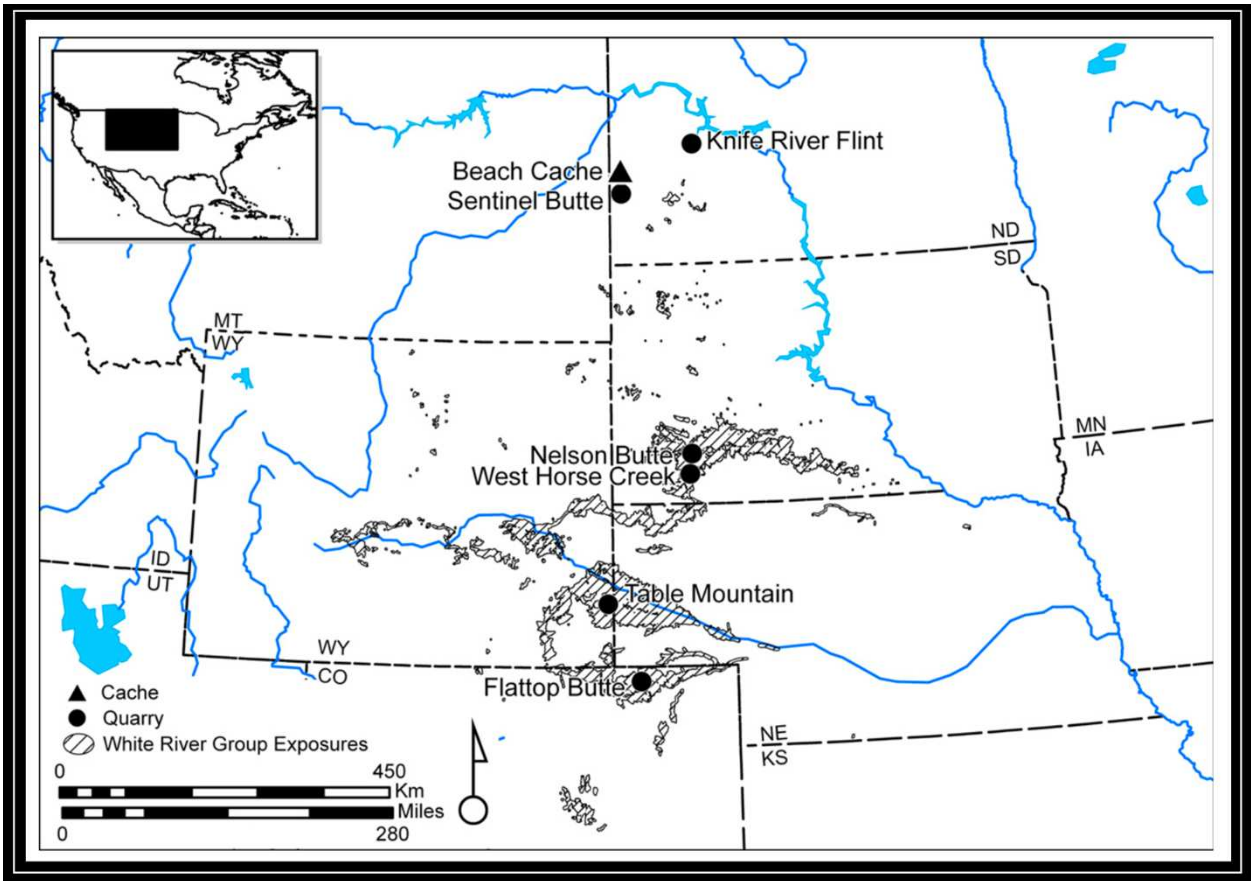

Figure 5. Map of exposures of the White River Group formation. From Huckell et al. (2011).

Geological Stratigraphy

The geologic stratigraphy at Flattop Butte is similar to other White River Group formations, but it is sufficiently distinct (having a much higher ash content, and few river channel sandstones or nodular beds) to have its own terminology (Galbreath 1953, Prothero 1996). The lower level, approximately18 meters thick, is termed the Horsetail Creek Member, and the upper level, approximately 21 meters thick, is termed the Cedar Creek Member (Figure 7) (Galbreath 1953; Prothero 1996).

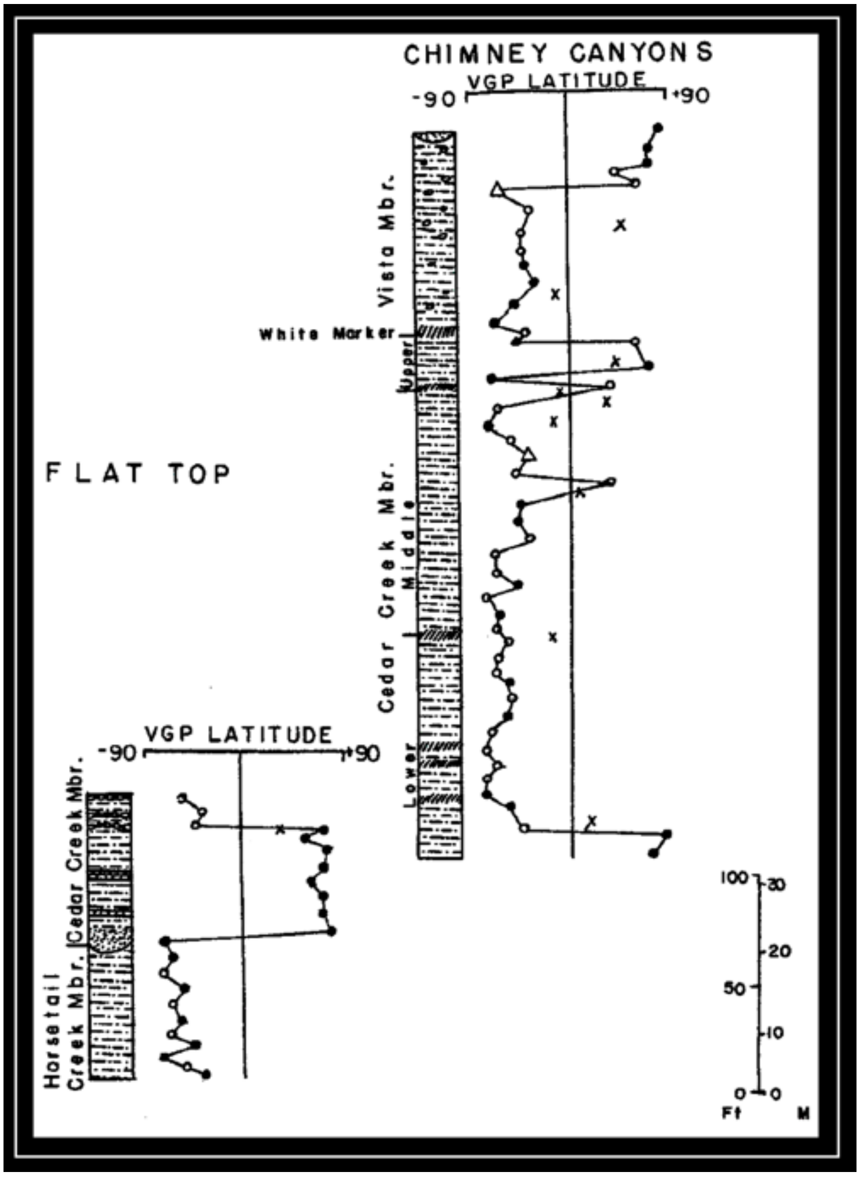

Figure 7. Geologic and magnetic stratigraphy of sections of the White River formation in Northern Logan County, Colorado, including Flattop Butte. From Prothero (1996).

Visual examination of Flattop Butte indicates that it consists of at least two, possibly three stacked, horizontal, limestone beds, separated by thick levels of lithified loess, covered by a layer of soil of varying depths, surrounded by an apron of eroded talus. This stratigraphy is most visible in the sides of an exposed, partially-detached, outcrop protruding from the southwestern tip of the butte that has been stripped of its top soil and much of its talus. As seen in Figure 8, at least two limestone beds, separated by thick deposits of lithified loess, are visible in the western profile of this outcrop.

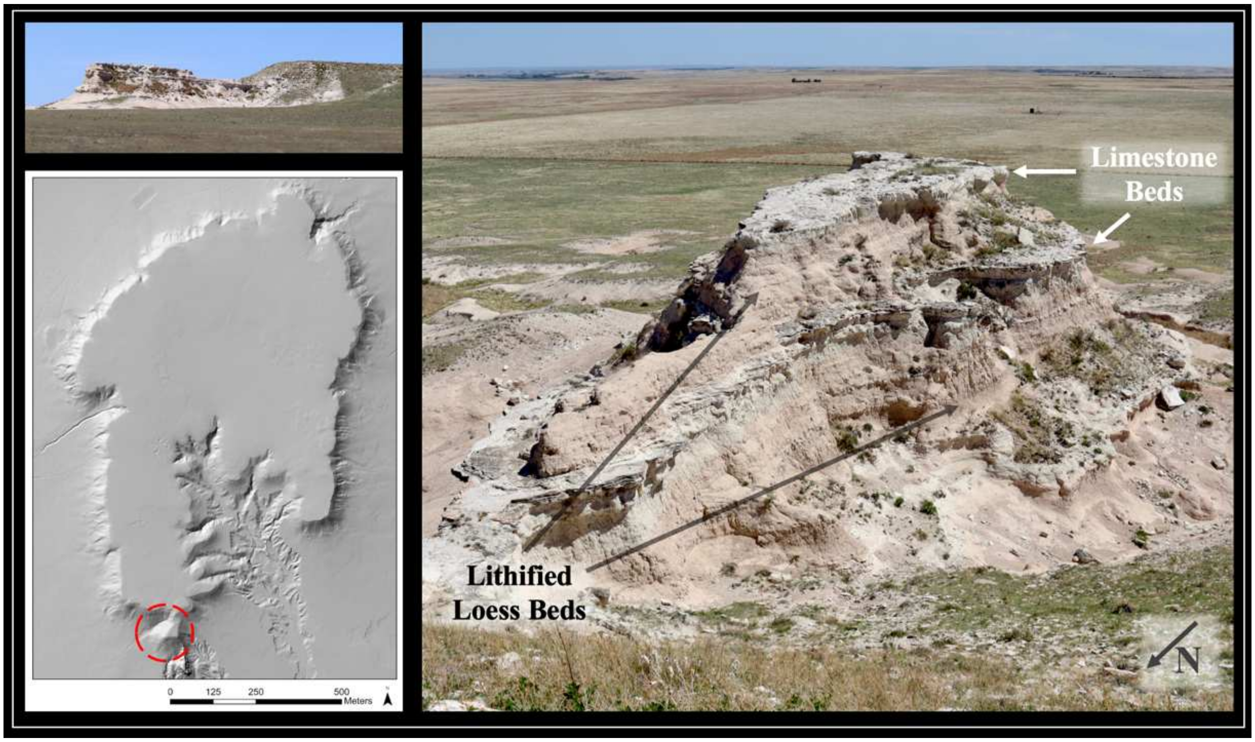

Figure 8. Semi-connected outcrop at the southwest edge of Flattop Butte, showing geologic stratigraphy of limestone beds separated by beds of lithified loess (photographs by the author).

These alternating beds of limestone and lithified loess were likely formed by a series of overlapping, freshwater, Oligocene lake beds that accumulated and deposited calcium carbonates sufficient to form limestone, dried, were covered over by loess, and then upon the return of wetter conditions, refilled, repeating the process (Ned Sterne, personal communication 2024). The uppermost limestone bed of the outcrop, forming its surface appears to be below the height of the surface of the remainder of the butte (Figure 8). This suggests that the chalcedony-bearing limestone bed nearest the surface of the main body of the butte – the so-called caprock – may be absent from the semi-detached outcrop, having been long-ago stripped away by erosion.

Flattop Chalcedony

Flattop Butte is the source of Flattop chalcedony, a highly sought-after ancient tool-stone bedded within the soil-covered, limestone caprock that forms the top of the butte (Figure 9) (Ahler 1977; Greiser 1983; Hoard et al. 1992). The flaking qualities of Flattop chalcedony make it an excellent material for toolmaking, having a highly conchoidal fracture, and leaving a prominent bulb of percussion, eraillure, and shatter scars when broken under pressure (Ahler 1977: Jensen 1973).

Figure 9. Limestone fragment with bedded Flattop chalcedony, recovered near excavation unit (photograph by the author).

Mineralogical Description and Associations

Flattop chalcedony is a high-quality, microcrystalline, translucent silicate (Ahler 1977; Hoard et al. 1992). The term chalcedony is used loosely here to describe any fine-grained, translucent stone (Ahler 1977; Greiser 1983).

Flattop chalcedony is one variety of a larger group of cryptocrystalline, translucent silicates known as the White River Group silicates (WRGS). They are so named because they outcrop in portions of the White River Group Formation in northeastern Colorado, southwestern South Dakota, western Nebraska, and southeastern Wyoming (Figure 5) (Miller 2010). In addition to Flattop chalcedony, other named varieties of WRGS include West Horse chert and Scenic chalcedony from South Dakota (Nowak and Hannus 1985), Sentinel Butte chert from North Dakota (Huckell et al. 2011), and Table Mountain chert from Wyoming (Hoard et al. 1993; Koch and Miller 1996).

Flattop chalcedony was formed when silica-rich fluids percolated through cracks and fissures in the limestone bed that now forms the caprock of Flattop Butte, depositing silica minerals in these spaces, which formed a solid lenses of microcrystalline, translucent silicate in the limestone formation (Boen et al. 2021). Color differences observed in the materials at Flattop Butte are the result of variations in the mineral composition of the rocks that were dissolved and incorporated into the chalcedony as it was forming. (Boen et al. 2021).

Color

Flattop chalcedony appears in a variety of colors that have been described in a variety of often complex ways. Following Ahler (1977), and for ease of analysis, the color varieties of Flattop chalcedony are simplified here and sorted into four general color-name groups: purple, red, brown, and white. Representative examples are pictured below in Figure 10. Using the Munsell Rock Color Charts (2011), these four colors correspond most closely to: (i) Pale Red Purple, 5RP 6/2 (for purple), (ii) Grayish Red, 5R 4/2 (for red), (ii) Pale Brown, 5YR 5/2 (for brown), and White, N9 (for white).

Figure 10. Representative examples of the four color-varieties of Flattop chalcedony (photographs by the author).

The white, opaque variety of Flattop chalcedony has in some cases been described as chert, rather than chalcedony (Ahler 1977; Jensen 1973). Nonetheless, all of the color varieties (including white) are referred to here, collectively, as Flattop chalcedony, as is the more common practice (e.g. Wheat 1979).

In addition to visual color varieties, Flattop chalcedony has been described as displaying additional color characteristics when exposed to different wavelengths of ultraviolet light. Hofman et al. (1991:302) note that samples of Flattop chalcedony recovered at the site have a distinctive “green mottled” response to shortwave ultraviolet light, with the mottling appearing as bright green speckles in a dull green or gray-green matrix. When exposed to longwave ultraviolet light, most samples of Flattop chalcedony are reported to exhibit orange areas, typically toward weathered surfaces or cortex (Hofman et al. 1991:302). Because this orange coloring does not appear under shortwave ultraviolet light, Hoffman et al. suggest that it provides a useful means of distinguishing Flattop chalcedony from other similar chalcedonies (1991:302).

Prevalence and Spatial Distribution of Color Varieties

As part of the survey work conducted here (described in more detail elsewhere), a study was undertaken regarding the prevalence and relative distribution of the different color varieties of Flattop chalcedony appearing in high-density debris areas examined across the butte. Details of the methods employed, and the results obtained in this study are set forth in Appendix B.

In summary, purple is the most common color variety of Flattop chalcedony, accounting for nearly 37% of the total volume of material observed on the surface of the high-density debris areas examined. The next most common color variety was white, accounting for 25% of the material observed at these locations, followed by brown at 22%, and red at 16%. In addition, it was observed that the purple, brown, and white color varieties appear together in almost all (more than 94%) of the locations examined, with the red variety appearing at only 69% of these locations (Appendix B).

Other Visual Characteristics

In addition to color, a number of other visual characteristics have been associated with Flattop chalcedony. For example, typical specimens of the purple, red, and brown varieties: (i) are smooth to the touch, with the more translucent pieces being the smoothest, (ii) exhibit a dull luster, and (iii) often display white, purple, or red banding or inclusions, with white sub-translucent inclusions being the most common (Carlson and Peacock 1974; Greiser 1983; Hoard et al. 1993; Jenson 1973). Finally, cortex of either a hard-white or light gray limestone, or white chert, is frequently present on flakes and worked pieces of Flattop chalcedony (Carlson and Peacock 1974; Hoard et al. 1992; Wheat 1979).

Other White River Group Silicates

As previously noted, Flattop chalcedony is considered part of a larger group of microcrystalline, translucent silicates known as the White River Group silicates (WRGS). These related lithic materials are named by reference to the White River Group formation because it is the smallest geological stratigraphic unit that includes all of them (Hoard et al. 1993). Before 1984, Flattop Butte was the only known source of WRGS (Koch and Miller 1996:1). Since that time, four other sources have been located, and four named varieties of WRGS have been identified, in addition to Flattop chalcedony (Figure 11).

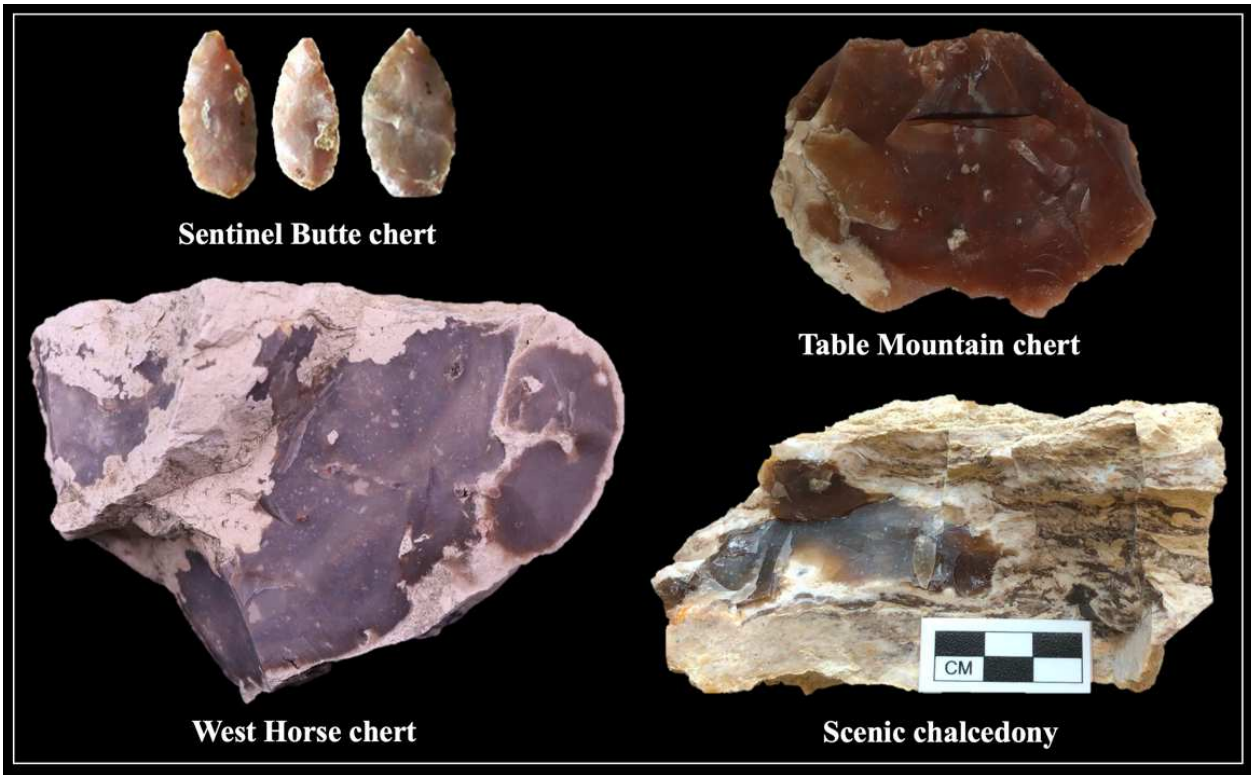

Figure 11. Other Named Varieties of White River Group Silicates (WRGS).
From Boen et al. (2021); CMPA lithics collection; Huckell et al. (2011); Toft lithics collection.

The first two named varieties to be identified are West Horse chert and Scenic chalcedony, both having their source at the Nelson Butte and West Horse Creek quarries in the White River Badlands of southwestern South Dakota (Lueck and Butterbrodt 1984; Nowak and Hannus 1985). The next named variety of WRGS to be identified is Table Mountain chert, sourced at the Table Mountain quarry in east-Central Wyoming (Hoard et al. 1993; Koch and Miller 1996). The final, and most recently discovered named variety and source of WRGS is Sentinel Butte chert, having its source at the Sentinel Butte quarry in North Dakota (Huckell et al. 2011). Each of these named varieties and their sources, together with methods that have been used to distinguish them from other varieties of WRGS, are discussed in more detail in Appendix C.

History of Archaeological Investigation at Flattop Butte

Despite the importance of Flattop Butte throughout prehistory as a lithic source in the Central Plains, the site itself has been the subject of only cursory archaeological examination. The history of these published, on-site investigations is detailed below.

The first unambiguous reference to Flattop Butte in the archaeological literature occurs in the second volume of E. B. Renaud's pioneering *Archaeological Survey of Eastern Colorado* (1932). Renaud reported being guided to "Flat Top hill" in early July 1930 by a Mr. F. E. Felkner (1932:24). He described the site as being located "five miles south" of two other sites visited on the same day, designated R 33-A and B, which he describes as being located "respectively in Smith and Horseshoe Cañons, 21 miles north, 6 and 8 miles west of Sterling" (Renaud 1932:24). When combined, these coordinates accurately describe the location of Flattop Butte.[3]

Renaud gave the site the identifier R34[4], and described it as a "camp-site with tipi-rings, quarry and workshop" (1932:24). In his field notes, he described the campsite as being "large," consisting of "many tipi rings several still visible," estimated to be "6 to 8 paces across," located

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[3] In an earlier volume of his *Archaeological Survey of Eastern Colorado* Renaud mentions a "large quarry … found on a butte fifteen miles north and fifteen miles west Sterling" (Renaud 1931:62). This appears to be a reference to Flattop Butte, as it is the only butte northwest of Sterling, Colorado, much less one with a quarry on its surface, although the coordinates Renaud provides in this reference are 12 km east and 3 km south of Flattop Butte. Compounding the apparent error, Renaud describes this butte-top quarry as a source of "geyserite" (1931:62), a form of opaline silica often found as crusts or layers that develop around geysers, spouters and spring-vents (Campbell et al. 2015), not the cryptocrystalline silicate found at Flattop Butte.

[4] Although Renaud identifies Flattop Butte as R34 in his published report (1932:24), in his field notes, he refers to it as R-35, both when describing it as well as on a hand-drawn map of the area (1930:29a, 31). Adding to the confusion, later in his published report, Renaud refers again to R34, but this time not in reference to Flattop Butte, but rather in reference to a site to the north, in Chimney Cañon (1932:25), which appears to be the site Renaud originally designated R-34 in his field notes (1930:29a, 31).

"near [the] south end" of the butte (Renaud 1930:31). On this visit, Renaud collected three chipped stone specimens of Flattop chalcedony (Figure 12).

Figure 12. Flattop chalcedony specimens collected by E. B. Renaud in 1930 at Flattop Butte.
(Courtesy of the University of Denver Museum of Anthropology, Images 1762-1770, photographs by Sarah Carlson.)

While Renaud's 1930 visit to Flattop Butte is the earliest published, professional site visit, an earlier, non-professional visit, recorded in the site file of the State of Colorado Office of Archaeology and Historic Preservation, is worthy of note. This report takes the form of a 1981 letter from Milton J. Wilbur, a retired instructor at the University of Colorado at Boulder and former resident of Logan County, to the director of the Fort Morgan Museum (Wilbur 1981). In it, Wilbur reported visiting "Flat Top Mesa" in Logan County as a boy in 1919 where he recalled observing an “Indian village” at the site (Wilbur1981:1). His letter accurately described the physical characteristics of Flattop Butte and enclosed a map that corresponds with the site’s location (Wilbur 1981). While Wilbur made no mention of quarrying at the site, he corroborated Renaud’s (1932) description of the site as including tipi-rings, recalling that “[a]t the southwest corner [of the butte] there were not less than 20 teepe rings with a fire stone” (Wilbur 1981:1).

More than 40 years after Renaud’s 1930 visit, the next account of a professional visit to Flattop Butte was published in Richard Jensen’s (1973) *Point of Rocks Archaeological Survey*, part of a continuing program of the Nebraska State Historical Society to locate, record, and excavate prehistoric habitation sites throughout the state. In May and June 1971, Jensen and Ronald L. Kivett, assistant curator of the Society, surveyed, documented, and excavated prehistoric campsites and tipi rings on terraces and ridge-tops in far southwest Nebraska (Jensen 1973:159). In the course of this work, Jensen and Kivett crossed the Colorado border to visit what Jensen described as a “very extensive quarry site … in northwestern Logan County, Colorado … on a prominent mesa locally known as Flattop” (1973:164).

Jensen described observing quarry pits on surface of Flattop Butte, ranging in size from 20 to 40 feet (6 to 12 m) in diameter and up to 2.5 feet (.75 m) in depth, as well as evidence of quarrying activity along the lip of the butte where erosion-exposed chalcedony appears (1973:164). He also described observing workshop areas appearing across the butte littered with nuclei, cores, flakes, shatter, and hammerstones, as well as a few such work areas in the lowlands surrounding the butte (Jensen 1973:164). During his visit, Jensen gathered approximately 1,300 otherwise undescribed specimens, about one-half selected randomly and the other half representing all of the material from the surface an area measuring three feet squared (1973:164).[5] In addition to quarry pits and workshops, Jensen also described observing five tipi rings, ranging in diameter from 14 to 18 feet (4.3 to 5.5 m), near the southern edge of the butte (1973:198). Jensen did not provide more specific coordinates for the tipi rings because, as he explained, "the site was visited late in the field season, and there was not sufficient time to draw a map" (1973:198).

Three years after Jensen's visit, Larry D. Banks, Dennis Stanford, Waldo Wedel, and Mike Toft visited Flattop Butte in the summer of 1974 (Banks 1986:75). This visit was carried out in connection with the then ongoing investigation of the Jones-Miller bison butchery site, approximately 130 km southeast of Flattop Butte, where Hell Gap projectile points and other tools made of Flattop chalcedony (among other materials) were recovered (Stanford 1978).

Banks described observing Flattop chalcedony chert appearing along the slopes of the butte within the upper three meters of the surface, with other nodules occurring as drift around the periphery (1986:73). He also reported observing "highly visible" shallow quarry pits, discernable "because of the greener and higher grass which grows in the shallow depression (Banks 1986:73-74). He suggested that a pattern of quarrying use at the site may have progressed from northeast to southwest, based on his observation that the southwestern pits are slightly deeper and larger, suggesting that the northeastern pits had been subject to a greater degree of weathering, and were therefore older (Banks 1986:74). Banks also reported observing erosion of the butte scarp that appears to have begun from quarry pits acting as small reservoirs in wet periods allowing solution cavities to develop leading to gullying around the butte edge, which if true could mean that a number of original quarry pits may no longer be present (1986:74).

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[5] Inquiries were made to the Nebraska Historical Society regarding the disposition of Jensen's collections from Flattop Butte, but no relevant records or collections were located.

Two years later, in 1976, Sally T. Greiser and a crew from the University of Colorado at Boulder made a short visit to what she identified as the "Flattop Mesa chalcedony quarry (5LO34)" (1983:6). The report of this visit, and the work performed during it, were published in 1983 in the journal Southwestern Lore (Greiser 1983). In the 40-plus years since its publication, this report has been cited on countless occasions by archaeologists in the region as the definitive statement on Flattop Butte.

In this report, Greiser described the surface of the butte as being "littered with hundreds of thousands of flakes, cores, some unfinished tools, preforms hammerstones," as well as discrete activity areas (1983:7). She noted that, although chalcedony is exposed at eroded edges of the butte, most of the material appears to have been removed from digging into the limestone caprock from the top (Greiser 1983). Greiser reported observing an estimated 200 prehistoric quarry pits on the butte-top, 2-10 meters in diameter, taking the form of depressions with associated refuse mounds (1983).

During their visit, the Greiser crew excavated a 6 x .05-meter test trench through the center of a quarry pit, including a portion of the associated refuse mound (1983) (Figure 12). This work is described as being performed over a six-hour period by a crew of six using picks and shovels (Greiser 1983). In the central portion of the pit, the top 50 cm of excavated material is described as being composed of fill consisting of scattered flakes and "chunks" of chalcedony, with chunks being pieces that appeared to have been broken away from a larger mass and discarded, likely because of their small size or unusable proportions (Figure 12) (Greiser 1983:9-10). Beneath this 50 cm fill of flakes and chunks, Greiser reports reaching a 40 cm level consisting of a heavy concentration of fractured and disturbed "slabs" of limestone in the approximate position of the original caprock deposit, interspersed with chunks of chalcedony (Figure 13) (1983).

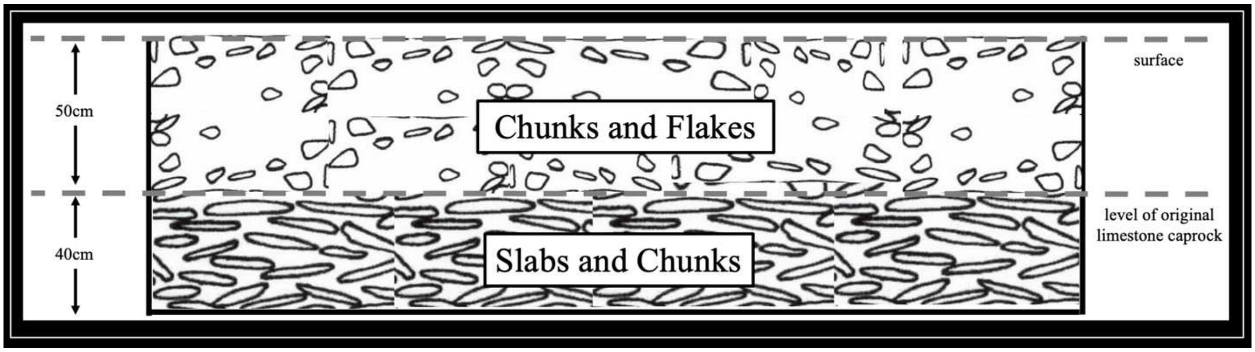

Figure 13. Profile of Greiser's 1976 test trench in a quarry pit, showing fill types. Modified from Greiser (1983:Figure 5)

In the refuse mound surrounding the pit, Greiser reported finding large masses of poor-grade chalcedony rejects, hundreds of flakes (many of them being decortication flakes), core remnants, and a large quantity of limestone slabs (1983). In the area surrounding the pit, Greiser reported observing several rejected biface blanks, with angles too obtuse for further reduction (1983).

Over twenty years after Greiser's work, in June 2006, Flattop Butte was visited by Brian Naze, then a graduate student at the University of Colorado at Boulder. Based on this visit, Naze prepared and filed a site reevaluation with the State of Colorado's Office of Historic Preservation (Naze 2006). Naze photographed quarry pits and documented two quarry pit clusters, which he identified as Quarry Pit Area A and Quarry Pit Area B (Figure 14) (Naze 2006).

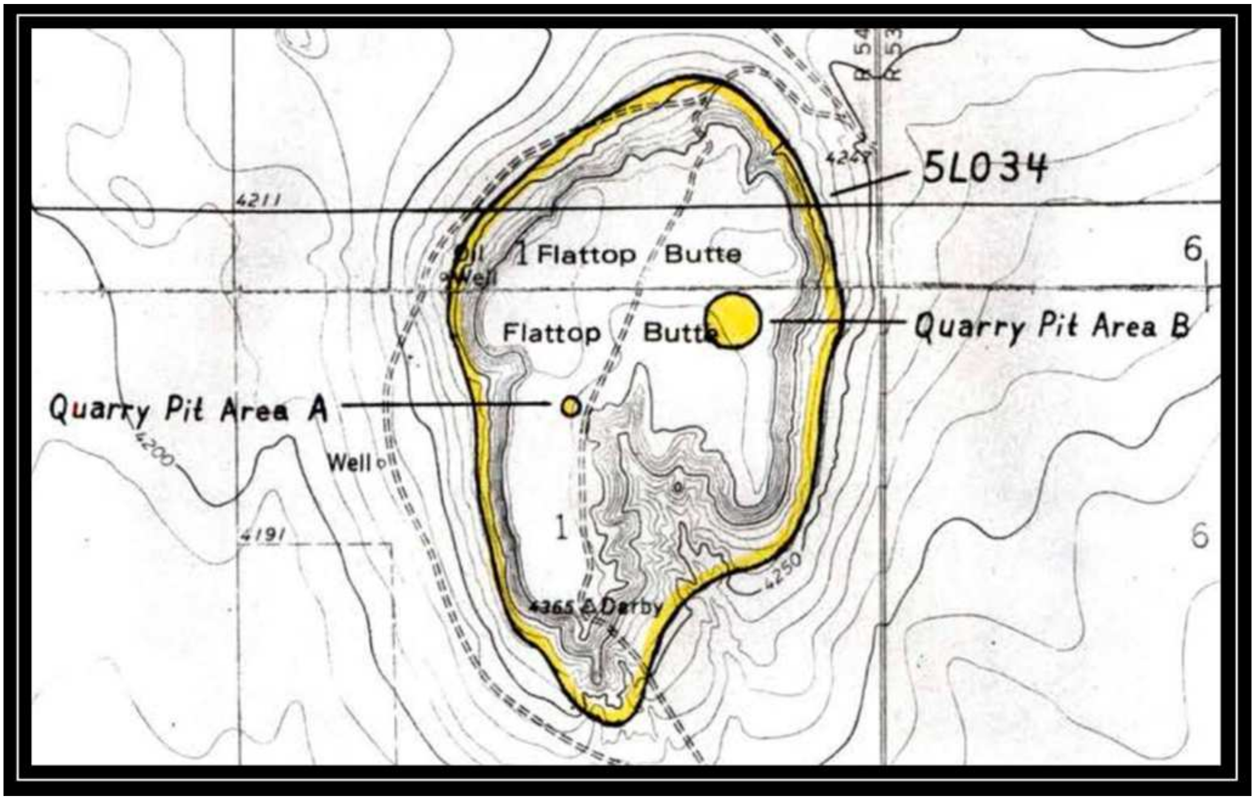

Figure 14. Quarry pit areas documented by Naze. From Naze (2006)

In Area A, Naze counted 13 quarry pits in an area measuring 50 meters in diameter (Naze 2006). He noted that the pits in the area were: (i) circular or oval, with some of the largest appearing to be elongated trenches, (ii) accompanied in most cases by adjacent spoil piles, and (iii) up to 1.5 meters deep as measured from the bottom of the pit to the top of spoil pile (Naze 2006). In Area B, Naze counted 20 pits in an area measuring 140 meters in diameter and noted that pits in this area were: (i) circular, (ii) difficult to discern, and (iii) shallow, with a maximum depth of about 0.5 meters (2006). Naze suggested that the shallower pits in Area B might be older than those of Area A as a result of accumulating more wind-blown sediment over time (Naze 2006).

Finally, in the summer of 2023, 47 years after Greiser's work, a crew from the Center for Mountain and Plains Archaeology (CMPA) at Colorado State University, led by the author, carried out the survey and excavation investigation described in this report. In the nearly five decades between the CMPA’s work and Greiser’s short visit in 1976, no other published, professional archaeological investigation occurred at Flattop Butte.

CHAPTER 3 – FIELD PROJECT AND DATA RECOVERED: SURVEY

The survey portion of the field projected reported here was carried out in June 2023 by the author, a crew of archaeology students from the CMPA (Aleah Kuhr, Kelsy Kreikemeier, Sebastian Schipman, and Leah Burke), and three experienced avocational archaeologists from Sterling, Colorado: Mike Toft, Grant Otzenberger, and Mike Dollard. The goals of the project, the methods employed, and the results obtained are reported hereafter.

Goals

The goal of the survey of the surface of Flattop Butte was to gather data relevant to the research questions described above. With regard to site chronology, the goal was to identify and recover in-situ, dateable cultural materials in an effort to associate different locations at the site with different periods of activity. With regard to spatial organization, the goal was to locate and identify evidence of specialized activity areas (quarry pits, secondary reduction workshops, and habitations) in an effort to examine how and to what extent different parts of the butte were utilized for different purposes by ancient peoples. Finally, with regard to mobility, the goal was to consider the extent and relationship of specialized activity areas for what they suggest about the organization and complexity of lithic production at the site and the time and effort expended by groups in lithic production at the butte.

Methods

The survey of Flattop Butte was carried out in three parts: (i) a walking survey of 78 individual 60x60m units covering approximately 50% of the surface of the butte, (ii) an intensive analysis of lithic reduction debris at 78 individual, 1 m^2, high-density debris areas located across the butte, one in each survey unit, and (iii) a more broad ranging examination of the entire surface of the butte, directed exclusively at locating evidence of ancient quarry pits. Each part of this survey is discussed in turn below.

Walking Sample Survey

The walking survey was carried out by placing a 60x60m grid over the surface of the butte, creating 160 individual 60 x 60 m units (Figure 15). Survey units were selected in a systematic, checkerboard pattern (indicated in yellow), resulting in a total of 78 individual 60 x 60 m survey units (Figure 15). This sampling method was selected in order to look for broad trends, given the crew size and time available to complete the field project.

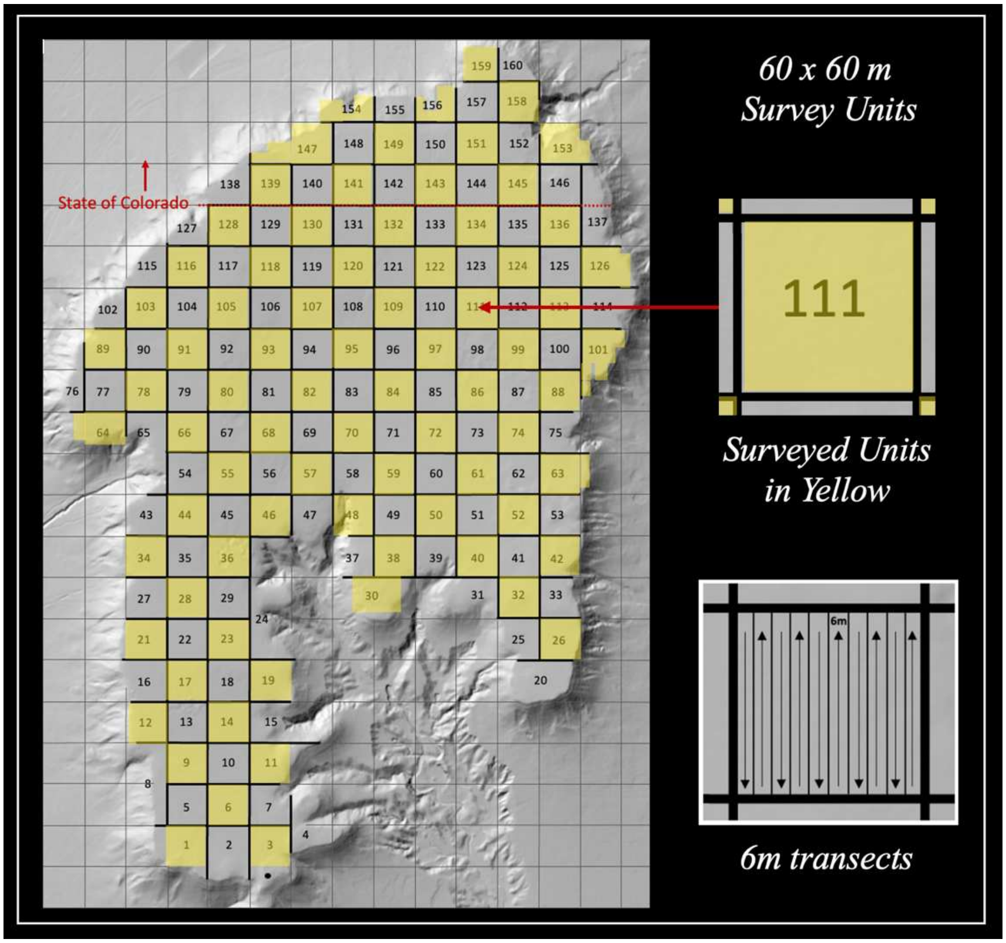

Figure 15. Survey design for Flattop Butte.

Once established, the survey units were assigned to individual crew members, who walked them in 6 m transects, for a total of 10 walking passes for each unit (Figure 14). The location of survey boundaries, and the mapping of all artifacts and features was carried out using handheld Garmin GPS units with an error rate generally around +/- 3 m. Surveyors were instructed to locate and map finished tools, bone tools, hammerstones, exotic (non-local) lithic materials, thermal features, and stone circles, if any, within the unit, with finished tools and bone tools also being collected.[6] Surveyors were also instructed to locate and compare high-density debris areas within each unit.

High-Density Debris Area Analysis

Quarrying debris on the surface of Flattop Butte tends to be concentrated in fairly well defined, often roughly circle-shaped, high-density debris areas with an average size of roughly one square meter (Figure 16). Therefore, in surveying the surface of the butte, an attempt was made to gather additional information from these high-density debris areas.

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[6] No collections were made from units north of UTM N 4526370 (units 138-160). This northernmost portion of Flattop Butte is owned by the Colorado State Land Board, which gave permission for survey, but not collection, on this portion of the butte. For these units, items that would have otherwise been collected were instead photographed, and left *in situ*.

Figure 16. High-density debris areas on the surface of Flattop Butte (photographs by the Flattop crew).

Specifically, surveyors were instructed to locate, photograph, and map a 1m^2 sub-unit in each 60x60m survey unit, placed at the center of the highest volume, high-density debris area in each survey unit. A map of the location of the high-density debris zones examined appears below as Figure 17.

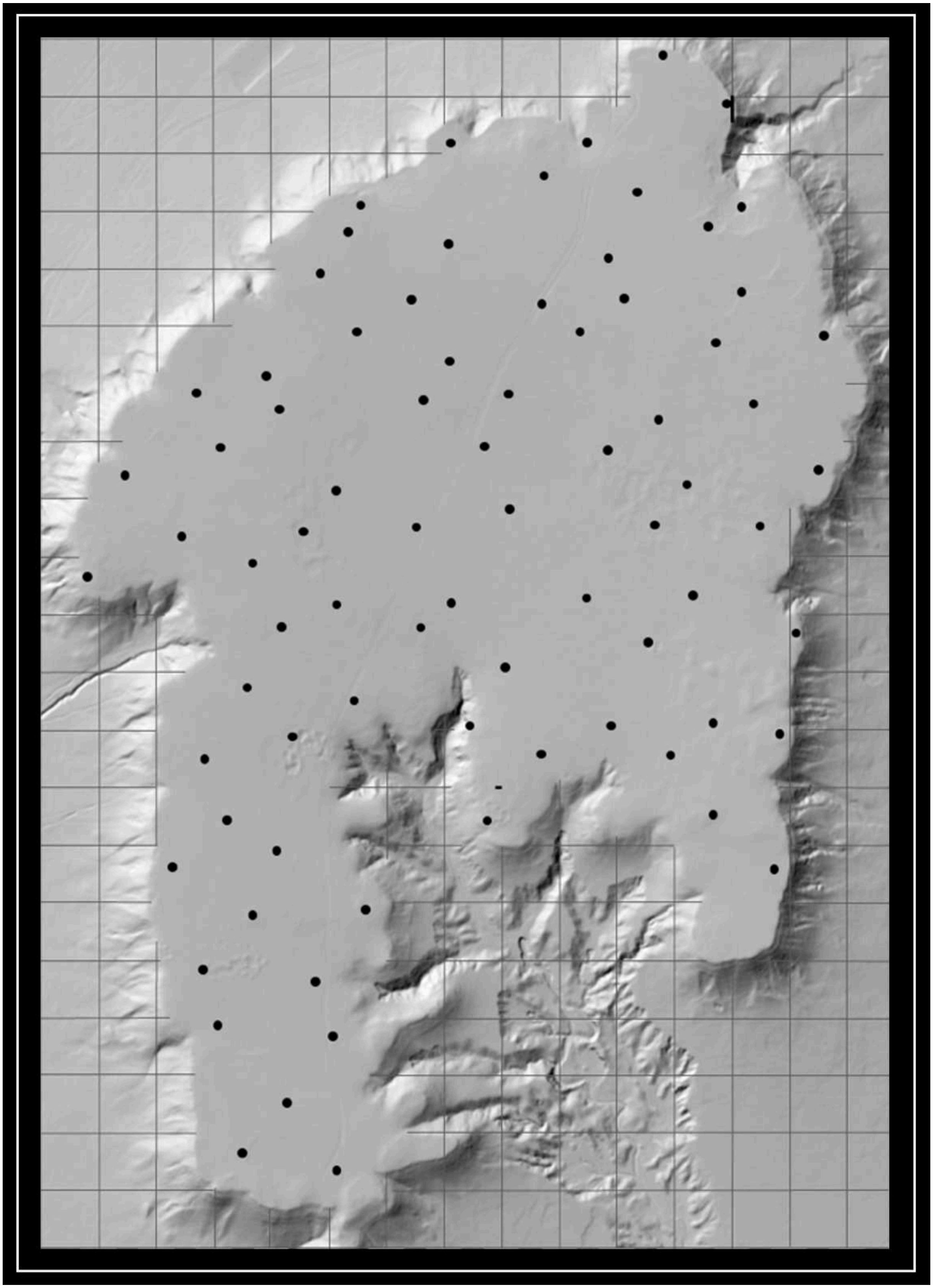

Figure 17. Locations of examined high-density debris zones.

Surveyors used a “dog-leash” (a pre-measured 56.5 cm length of cord tied at both ends to a nail) to define the boundaries of the circular 1m^2 sub-units and gathered and sorted all materials in each using a pre-marked sorting template (Figure 18). Surveyors also measured the total lithic debris in each 1m^2 sub-unit, by volume, in cm^3. For this purpose, lithic debris was defined as any stone material consisting of more than 50% Flattop chalcedony.

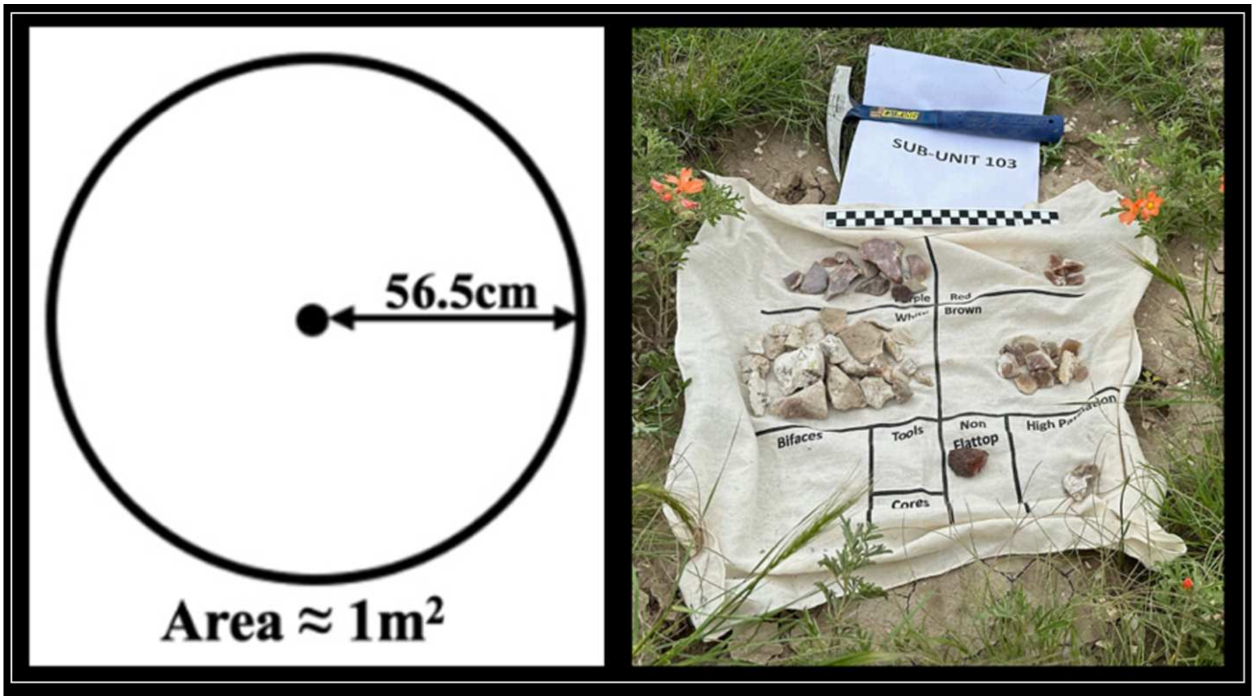

Figure 18. Marking and sorting procedures for high-density debris zones.

Next, surveyors were instructed to separate all lithic debris by color, using the four-part, purple, red, brown, white color scheme discussed above. For each color, surveyors were instructed to estimate its relative percentage of the total lithic debris and collect a representative sample. Then, surveyors were instructed to collect any tools, bifaces, cores, hammerstones or exotic (non-local) lithic materials found in the sub-unit.

Finally, surveyors were instructed to collect up to five examples from each sub-unit of lithic debris displaying high levels of patination,[7] a "translucent 'milky-white' appearance" that can form on the surface of fractured cryptocrystalline silicates such as Flattop chalcedony (Powers 2014:16). Patination formation is a subtractive, desilicification process caused when alkaline solutions attack exposed crystal grains in the surface of the material, leaching silica from between the crystals, etching and in some cases reducing their size, resulting in increased light scattering from the modified crystals and causing the observed white surface effect (Schmalz 1960; Hurst and Kelly 1961; Rottländer 1976; VanNest 1985; and Pawlikowski, et al. 2014). In limited circumstances, discussed in more detail in Chapter Five, patination can provide some indication of the relative age of artifacts of the same material, exposed to the same environmental conditions.

Quarry Pit Survey

Separate and apart from the survey described above of 78 individual 60x60m units and 1m^2 sub-units, crew members also surveyed the entirety of the butte for the purpose of identifying and mapping evidence of ancient quarry pits. These were mapped and recorded with a single coordinate, taken at a point representing the approximate center of the pit, using a handheld Garmin GPS.

Evidence of quarry pits took two main forms. First, some pits are apparent from the appearance of large depressions in the ground surface, often accompanied by what appear to be the remains of adjacent spoil piles (Figure 19). In other cases, where no visible depression is apparent, quarry pits were identified by the presence of marked changes in vegetation.

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[7] Where patinated debris appeared in a sub-unit, surveyors were instructed to collect up to five of the most heavily patinated specimens.

Figure 19. Quarry pit remains showing surface depression and adjacent raised spoil pile. From Naze (2006).

Specifically, a tall, dark-green variety of grass, later identified as western wheatgrass (*Agropyron smithii*) appeared to grow exclusively in and above ancient quarry pits. As seen in Figure 20, these isolated, circular to oval outcrops of western wheatgrass were easily distinguishable (both from field observations as well as in satellite imagery) from the surrounding buffalograss (*Buchloë dactyloides*) that dominates the foliage on the surface of the butte. Without exception, quarry pits that were identifiable from the presence of ground depressions were filled with tall stands of western wheat grass, which ended at the boundaries of the quarry pit. Similar, well-bounded, circular to oval outcrops of western wheatgrass could be seen covering not only surface depressions from ancient quarry pits, but also other adjacent locations with no, or only vaguely discernable, surface depressions.

Figure 20. Surface and satellite views of isolated outcrops of western wheat grass identifying quarry pit locations.

Based on these observations, all well-defined, circular to oval outcrops of western wheat grass were identified and mapped as quarry pits, regardless of the presence of a visible surface depression. This is consistent with observations by Banks who reported observing “highly visible” quarry pits on the surface of Flattop Butte that were discernable “because of the greener and higher grass which grows in the shallow depression” (1986:73-74). One of these presumed quarry pits, covered with western wheat grass, but with little or no evidence of a surface depression, was the subject of the excavation project discussed below, which confirmed that it is in fact an ancient quarry pit.

It is unclear why western wheatgrass would grow over ancient quarry pits, but not elsewhere on the butte. It may be that the disturbed mix of quarrying debris and fine-grained loess that appears to fill the quarry pits (as seen in both Greiser’s quarry pit test trench, and in the quarry pit excavation unit here), creates the kind of heavy, but well-drained soil that western wheatgrass prefers (USDA 2002)

Results

The results of the walking survey of the 60 x 60m units, the analysis of lithic reduction debris in the 1 m^2 sub-units, and the quarry pit mapping survey are reported in turn below.

Walking Sample Survey

The walking survey of the 78 individual 60x60m units resulted in the identification, collection, and mapping of numerous finished tools and hammerstones, the identification and mapping of exotic raw materials (not Flattop chalcedony), and the identification and mapping of a limited number of features and possible features. Each is discussed hereafter.

Finished Tools

Surveyors collected a total of 39 finished, chipped stone tools in the survey of Flattop Butte. This total consists of 26 scrapers (14 side scrapers, 12 end scrapers), four blades, three bifaces, three preforms, and three projectile points.[8] Photographs of these tools appear in Figure 21.

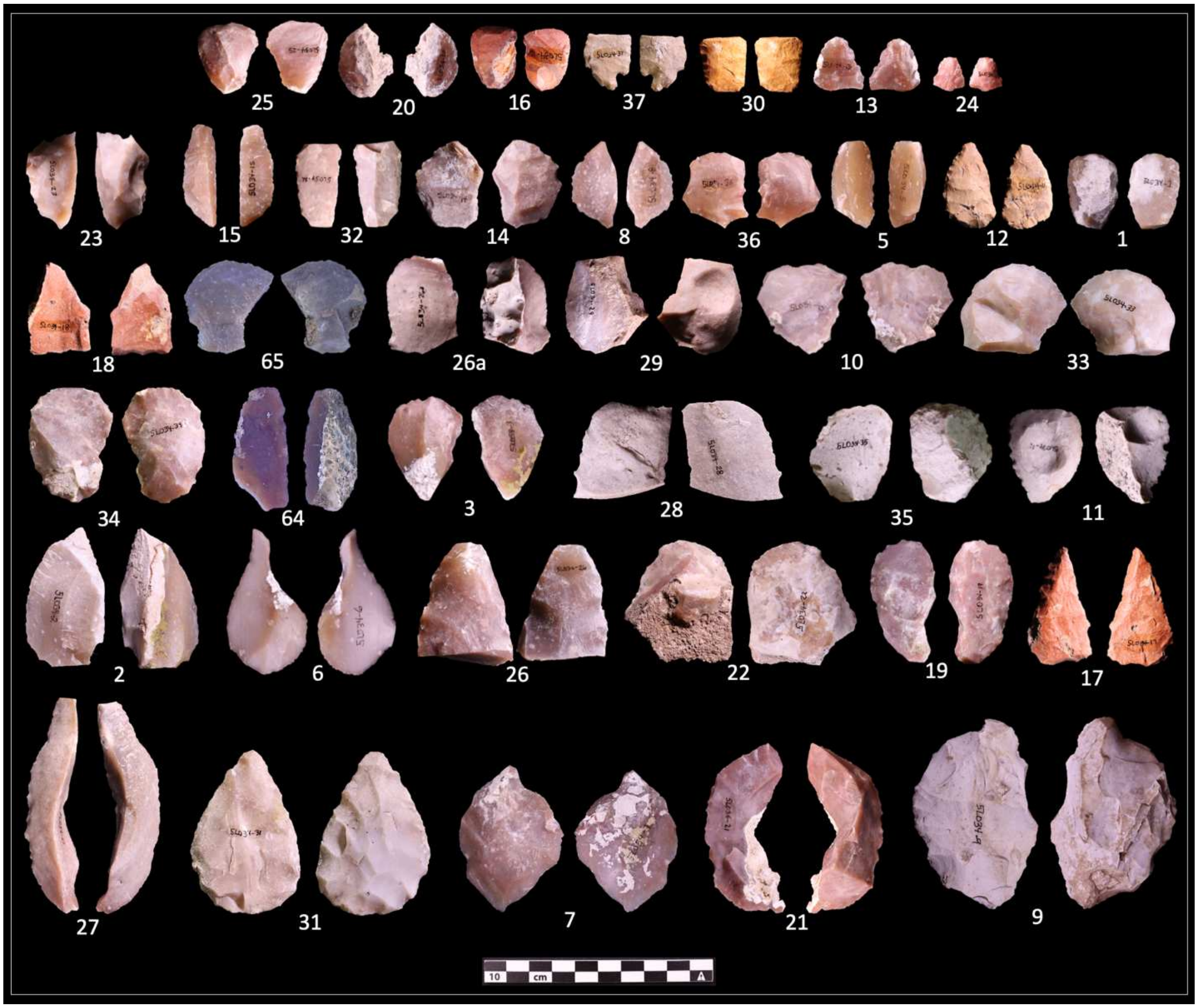

Figure 21. Finished tools collected in unit survey.

The type, location, measurements, raw material, cultural complex, and temporal period for these finished tools (where available) are set forth in Appendix D. Two of the tools appear to be

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[8] For descriptions of the tool types referenced here, see Andrefsky (2005:22-23, 77) (bifaces, preforms) and Hayden (2022:21, 32, 65, 72) (projectile points, end scrapers, side scrapers, blades).

temporally diagnostic: (i) the base of an Agate Basin projectile point (#30), dateable to between 12,500 and 11,500 calibrated years before the present (LaBelle 2005:Table 2.1), and (ii) the base and mid-section of a Duncan-Hanna dart point (#37), dateable to between 5700 and 2250 calibrated years before the present (Eighmy and LaBelle 1996).

A map showing the location, by type, of these finished tools appears in Figure 22, with the locations of scrapers are shown in purple, blades in blue, bifaces in green, preforms in yellow and projectile points in black. The location of the two temporally diagnostic projectile points are specifically highlighted.

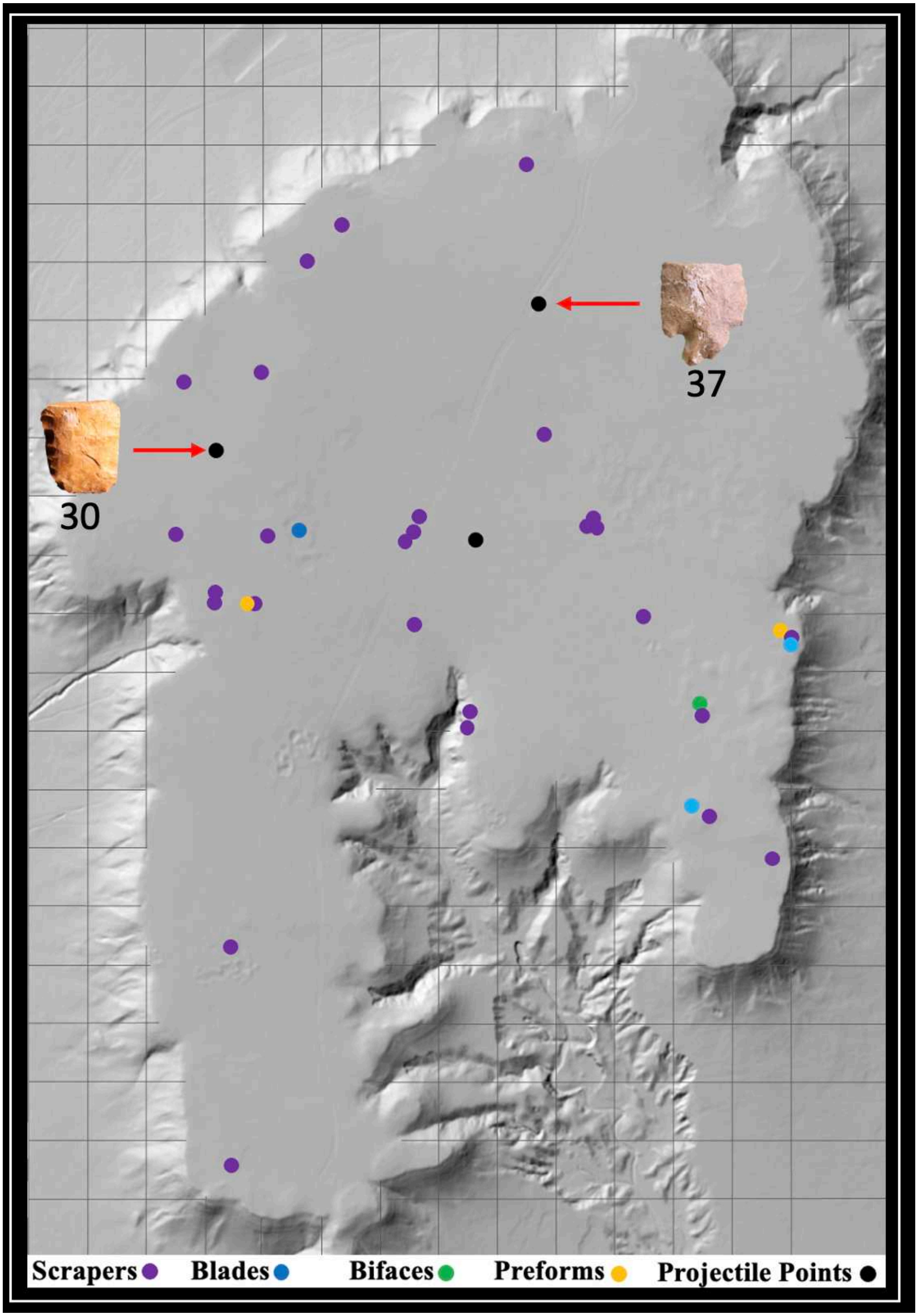

Figure 22. Locations of finished tools collected in unit survey.

Hammerstones

Surveyors identified, mapped, and (in some cases) collected a total 27 hammerstones in the survey of Flattop Butte. The location, measurements, and raw material, for these hammerstones (where available) are set forth in Appendix D. A map showing the locations where hammerstones were observed appears in Figure 23.

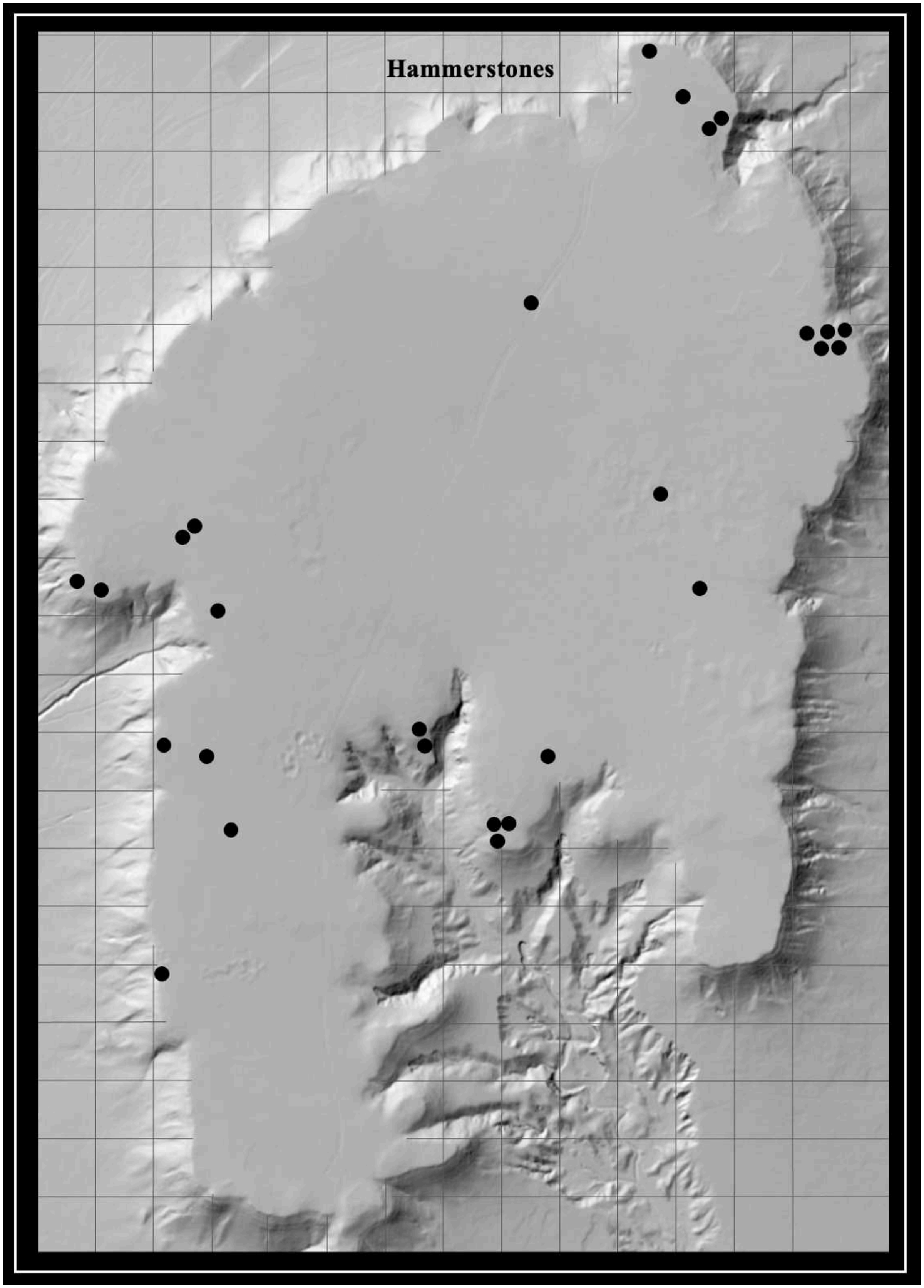

Figure 23. Locations of hammerstones mapped in unit survey.

Exotic Materials (non-Flattop Chalcedony)

Surveyors located, mapped, and collected a total of 37 examples of exotic (non-Flattop chalcedony) lithic raw materials on the surface of the 78 individual survey units. The lithic types, forms, and numbers of these specimens are summarized in Table 1 with additional detail set forth in Appendix E.

Table 1. Summary data of exotic materials (non-Flattop chalcedony) collected in unit survey.

Raw Material (General)	**Raw Material (Specific)**	**Number of Items**	**Tools**	**Hammer-stones**	**Flakes**	**Angular Debris**
Quartzite (QZT)	Unknown	14	1	11	1	1
Cryptocrystalline Silicate (CCS)	Smoky Hill Silicified Chalk (SHSC)	8	2	0	4	2
CCS	Unknown	4	0	0	3	1
QZT	Windy Ridge Quartzite (?) (WRQ)	3	1	0	2	0
Granite	Unknown	2	0	2	0	0
Unknown	Unknown	3	2	0	0	1
CCS	Trout Creek Chert (?) (TCC)	1	0	0	1	0
Quartz	unknown	1	0	0	0	1
Totals		37	6	13	11	5

Of the six finished tools made from exotic materials, a projectile point (#30), a preform (#12) and an endscraper (#16) are made from Smoky Hill silicified chalk (SHSC) (a/k/a Republican River/Smoky Hill/Niobrara jasper), which outcrops in stream drainages in southwest Nebraska and northwest Kansas, roughly 275 km to the southeast of Flattop Butte (Stein 2005). One endscraper (#28) is made of quartzite, possibly Windy Ridge quartzite (WRQ), which outcrops in the Southern Rocky Mountains of northern Colorado, 280 km to the southwest of Flattop Butte (Bamforth 2007; Black 2000). One piece of angular debris is chert, possibly Trout Creek chert (TCC), which outcrops in the Southern Rocky Mountains of Central Colorado, 325 km to the southwest of Flattop Butte (Chambellan et al. 1984). One projectile point (#4) is made from an unknown quartzite material. Finally, two tools, a preform (#17) and an endscraper (#18) are made of a material that cannot otherwise be identified.

Of the 13 hammerstone fragments made from exotic raw materials, 11 are made from an unknown quartzite material and two are made of an unknown granite material. Of the 11 flakes made from exotic raw materials, four are made of SHSC, three are made of an unknown cryptocrystalline silicate, two are made of quartzite (possibly WRQ), one is made of an unknown quartzite, and one is made of chert, possible Trout Creek chert (TCC). Finally, of the four pieces of angular debris made from exotic materials, two are made of SHSC, one is made of an unknown cryptocrystalline silicate, and one is made of an unknown quartzite.

Exotic materials were also recovered in the excavation unit discussed in Chapter Four. These include: (i) an arrow point made of Smoky Hill silicified chalk, (ii) an endscraper made of a non-Flattop cryptocrystalline silicate, possibly Alibates chert from the Texas Panhandle, roughly 620 km to the southeast of Flattop Butte (Bousman et al. 2011); (ii) and a preform made of quartzite, possibly from the Spanish Diggings quarry in eastern Wyoming, 280 km to the northwest of Flattop Butte (Reher 1991).

Assuming the accuracy of these raw material identifications, these finds show exotic materials being moved to, and discarded at, Flattop Butte from locations to the north, south, east, and west, including the High Plains of Wyoming, the Rocky Mountains of Colorado, the Central Plains of Kansas, and the Southern Plains of Texas (Figure 24), suggesting movements of ancient groups from these locations to Flattop Butte.

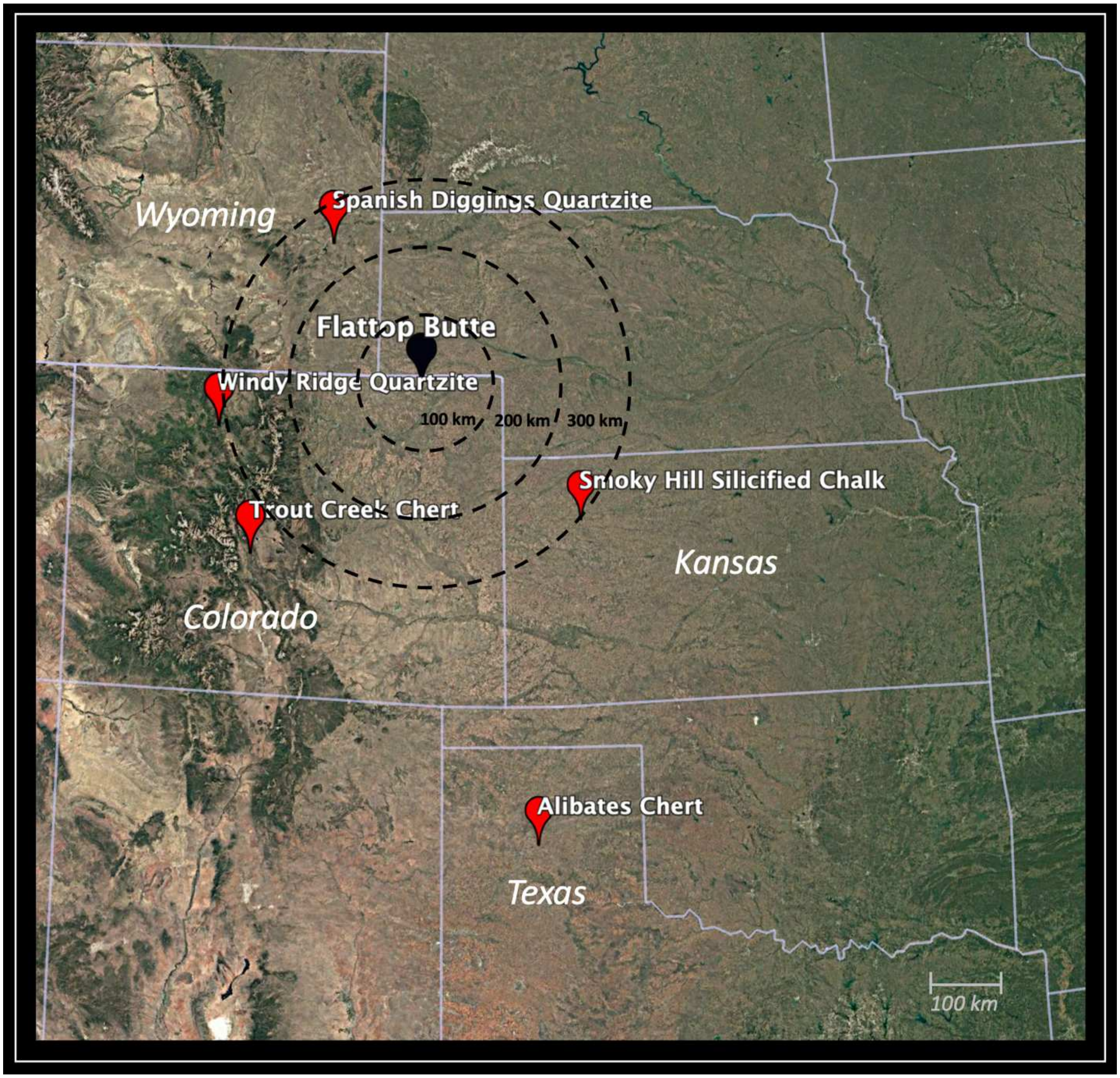

Figure 24. Origin of exotic (non-Flattop chalcedony) lithic materials recovered on-site.

Features

As part of the walking survey of the 78 individual 60 x 60 m units, surveyors were instructed to note the appearance of any features suggesting habitation locations, such as thermal features (hearths) and stone circles (tipi rings).

Stone Circles

As noted above, previous reports have indicated that stone circles were at one time present in the far southwest portion of the butte (Jensen 1973; Renaud 1932; Wilber 1981). Survey in this area failed to locate features that could be unambiguously identified as stone circles, as described in these prior reports.

However, at seven locations in the far southwest portion of the butte, small collections of limestone cobbles, larger than typical limestone materials in the immediate surroundings, were observed (Figure 25). These cobbles were found in groups from four to ten and were spaced such that they could plausibly have once formed portions of now incomplete, partially-buried, stone circles as observed by previous visitors to the site. It is also possible that they are simply random cobbles.

Figure 25. Possible stone circle at far southwest of Flattop Butte (left), and possible single stone element (right).

As shown in Figure 26, these possible stone circles are all located in the far southwest portion of the butte, consistent with the reports of Jensen (1973), Renaud (1932), and Wilbur (1981).

Figure 26. Locations of possible stone circles on Flattop Butte.

Thermal Features

One thermal feature was located in the walking survey. It consisted of a scatter of small, thin, burned pieces of limestone eroding from the south-center edge of the of the butte, where an erosional wash begins to divide the landform into western and eastern peninsulas (Figure 27). The top of the thermal feature begins around 21 cm below the surface of the cut bank and extends 13 cm deep, with a width of around 11 cm.

Figure 27. Thermal feature identified in walking survey.

Two small, irregular pieces of red Flattop chalcedony appear just under and to the right of burned rock concentration. No charcoal was observed, although a piece of the burned rock was collected. This sample was submitted for radiocarbon dating of the blackened organic residue on its surface, and a date was returned of 2540 ± 25 rcybp, which calibrates to approximately 2700-2600 calibrated years before the present.[9] The full report for this radiocarbon date appears in Appendix F.

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[9] Calibrated radiocarbon dates reported herein were derived using the OxCal 4.4 software (Bronk Ramsey 2009) and the IntCal20 calibration curve (Reimer et al. 2020) at a 95.4% probability.

High-Density Debris Area Analysis

As previously noted, in the course of surveying each of the 78 individual 60x60 meter units, surveyors were instructed to locate, photograph, map, and analyze the contents of a 1 m^2 sub-unit, placed at the center of the highest volume, high-density debris area in the unit. For each of these sub-units, surveyors collected information regarding debris density, color distribution, and patination.

Debris Volumes

The amount and distribution of quarrying debris present at various locations on the butte can yield information regarding not only where chalcedony was extracted and reduced but also the logistical organization of these activities. The total volume of chalcedony reduction debris (in $cm^{3)}$ appearing on the surface of each of the 78 individual 1 m^2 sub-units is set forth in Appendix K. The relative differences in debris volume between sub-units, and the spatial distribution of high- and low-density areas, are graphically illustrated in Figures 28 and 29. In Figure 28, relative debris density at various locations is depicted by both color and size. The circles on the map are centered on each of the 78 individual sub-units. Their color is determined by the relative volume of debris in the sub-unit, ranging from very high (red) to very low (blue). The diameter of the colored circle represents the absolute volume of debris in each sub-unit, relative to the other 77 sub-units.

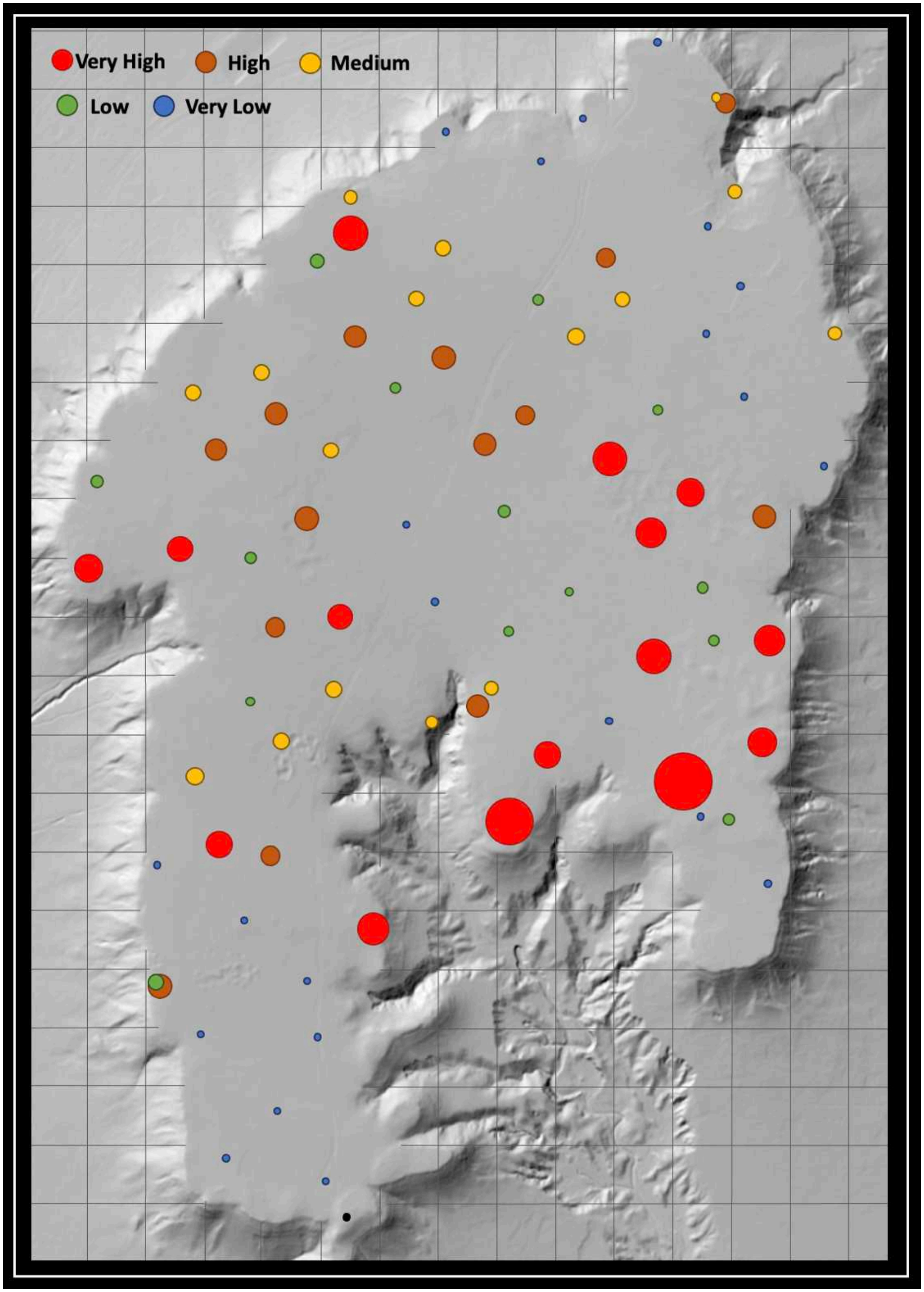

Figure 28. Visual representation of relative debris volume in 78 measured high-density debris sub-units.

In Figure 29, relative debris density is graphically depicted by color, with the volume of debris between the sub-units extrapolated using inverse distance weighting.[10] As discussed in more detail in Chapter 6, this data shows a clear pattern of quarrying debris being concentrated in the central portion of the butte, with no high-density areas being located in the southern portion, and only scattered high density areas appearing in the northern portion.

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[10] Inverse distance weighting estimates the volume of unmeasured areas based on the average volume of nearby measured areas, with closer areas having a greater influence on the estimate.

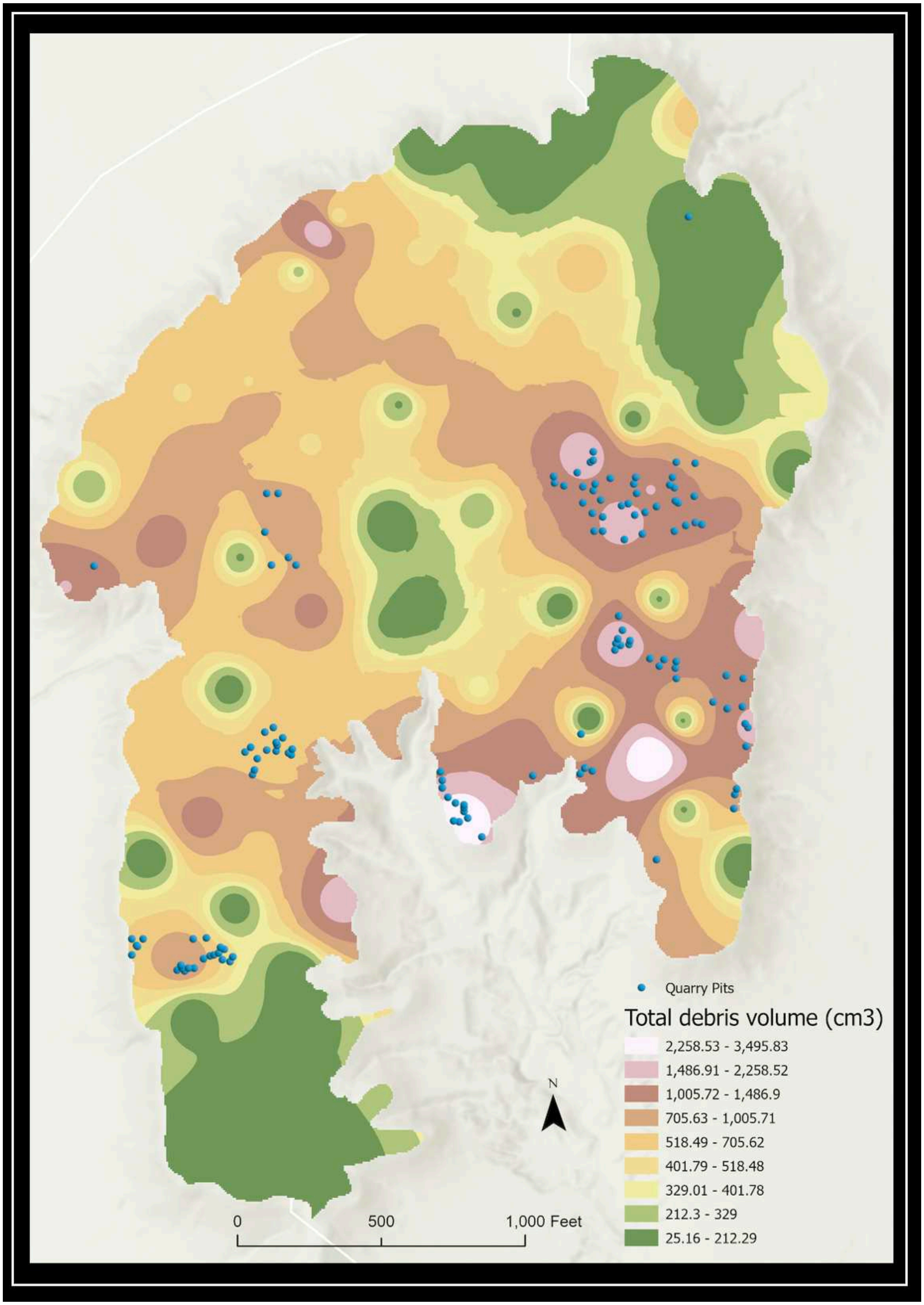

Figure 29. Quarrying debris volume by area, extrapolated using inverse distant weighting.
Created by Joshua Reyling, Geospatial Centroid, Colorado State University.

Color Distribution

As previously noted, in addition to measuring the total volume of quarrying debris in each of the 78 individual $1m^2$ sub-units, surveyors estimated the relative percentage of Flattop chalcedony debris by color in each sub-unit. The results of these efforts are set forth in Appendix B, and are graphically represented in Figure 30 using inverse distance weighting. Additional information regarding color distribution is set forth in Appendix B.

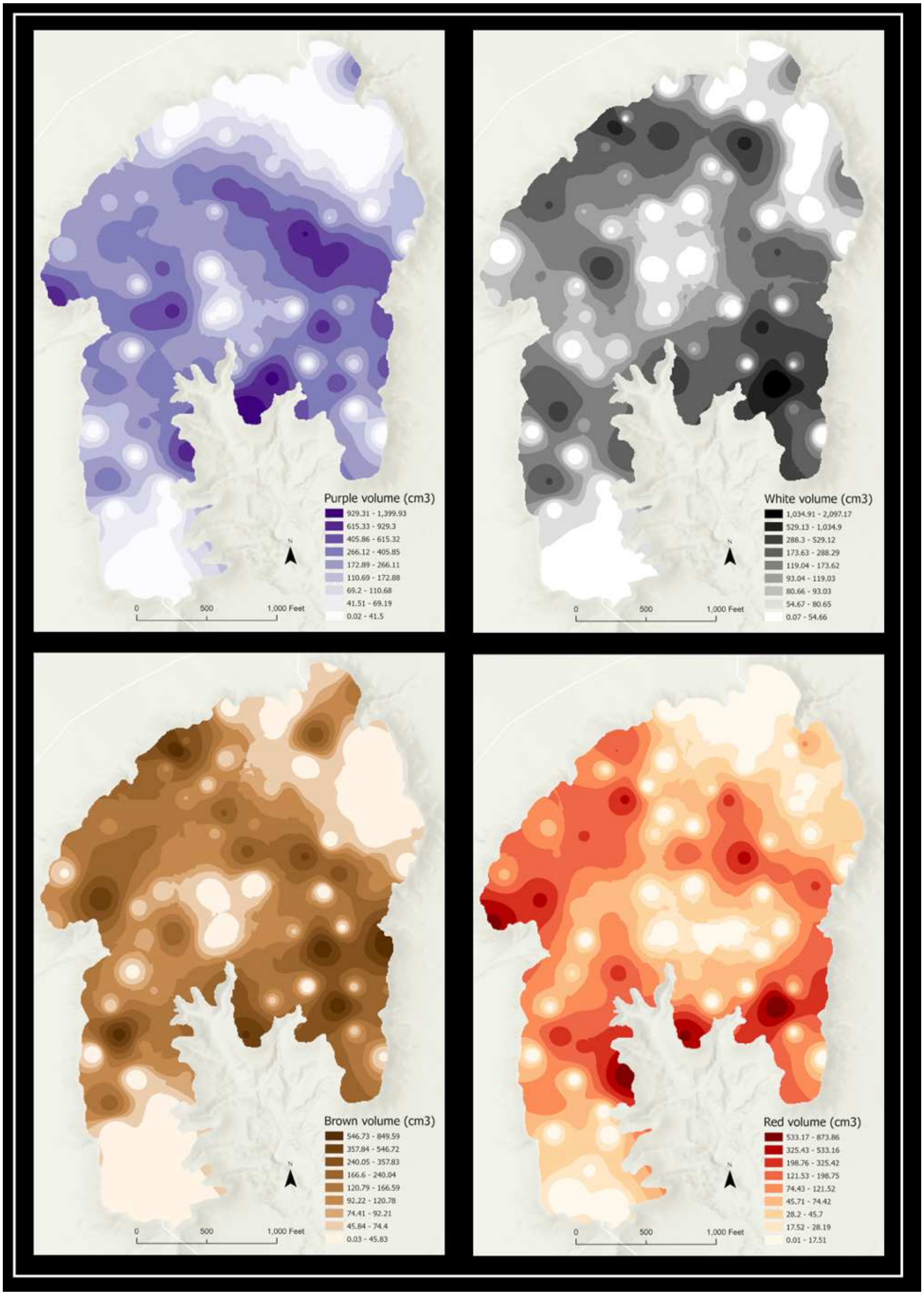

Figure 30. Maps of spatial distribution of color varieties of Flattop chalcedony based on volumes in measured high-density debris zones, and extrapolated using inverse distant weighting. Created by Joshua Reyling, Geospatial Centroid, Colorado State University.

Patination

Surveyors identified and collected a total of 134 samples of quarry reduction debris showing discernable surface patination from 67 of the 78 individual $1m^2$ sub-units. As discussed in more detail in Appendix G, patination is of interest here because its formation tends to increase over time, meaning that the relative thickness of patination on chert, flint, and chalcedony artifacts can be indicative of their relative age, where (as here) the chemical composition of the artifacts' base materials are the same, and the local climate conditions and soil types where the artifacts were collected are similar (Clark 1985; Frederick et al. 1994). However, even where these variables are controlled, error rates can still be significant for individual artifacts (Clark 1985; Frederick et al. 1994). Thus, in these circumstances, patination thickness can provide a tentative indication, albeit not definitive, of relative age (Fredrick et al. 1994).

Therefore, the patination appearing on each of the 134 samples of quarry reduction debris showing discernable surface patination from the surface of 67 of the 78 individual $1m^2$ sub-units was examined using low-power (20x) magnification, and the relative thickness of observed patination (the amount of color change caused by the desilicification process) appearing on each specimen was compared with the other samples. This resulted in a rank ordering of the 134 patinated samples from highest to lowest. The location by survey unit and rank-ordering of all patinated specimen collected[11] are set forth in Appendix G. As discussed in Chapter Five, the relative patination observed on chalcedony debris provided support for other, independent dating of certain locations and related features.

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[11] For Units 147-159, where permission to collect was not permitted, patinated samples were photographed *in situ*.

Quarry Pit Survey

As previously described, separate and apart from the survey of 78 individual 60 x 60 m units, a walking survey of the entire butte was conducted with the sole purpose of identifying and mapping quarry pits. Those efforts identified and mapped 128 quarry pits. The coordinates of the approximate center-points of these quarry pits are provided in Appendix E. A map showing the location of the quarry pits appears in Figure 31.

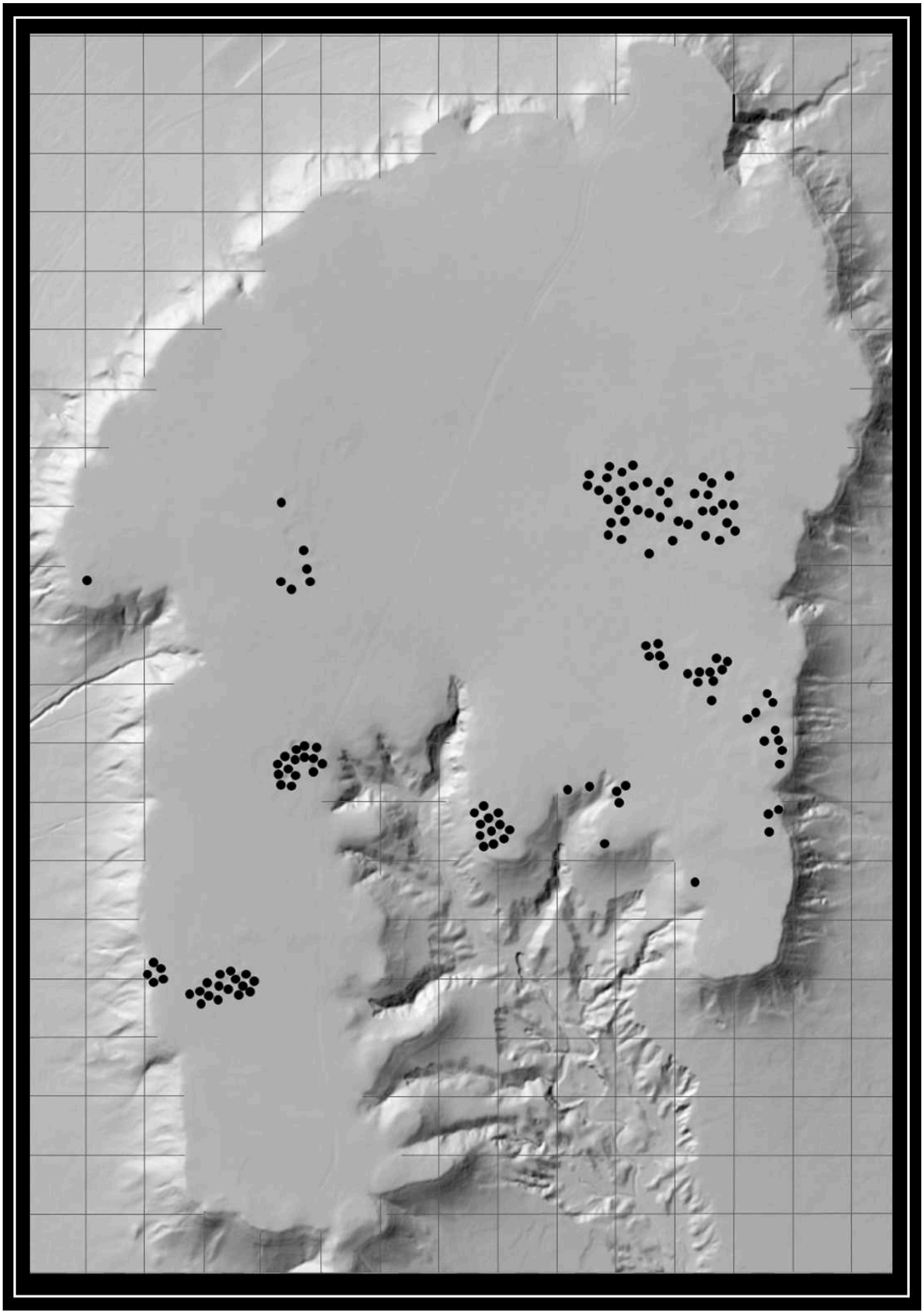

Figure 31. Quarry pit locations.

As shown in Figure 32, the quarry pits visible on the surface of Flattop Butte are concentrated in seven visually defined clusters spread across the Central portion of the butte, designated Clusters A through G. Cluster B is the largest, with 40 quarry pits, followed by Cluster D with 26 pits, Cluster G with 21 pits, Cluster C with 15 pits, Cluster E with 12 pits, and Clusters A and F with 5 pits each. In addition to the 124 quarry pits concentrated in these clusters, four solitary, “orphan” pits appear outside and isolated from these clusters, standing 45 to 195 meters from their nearest cousin.

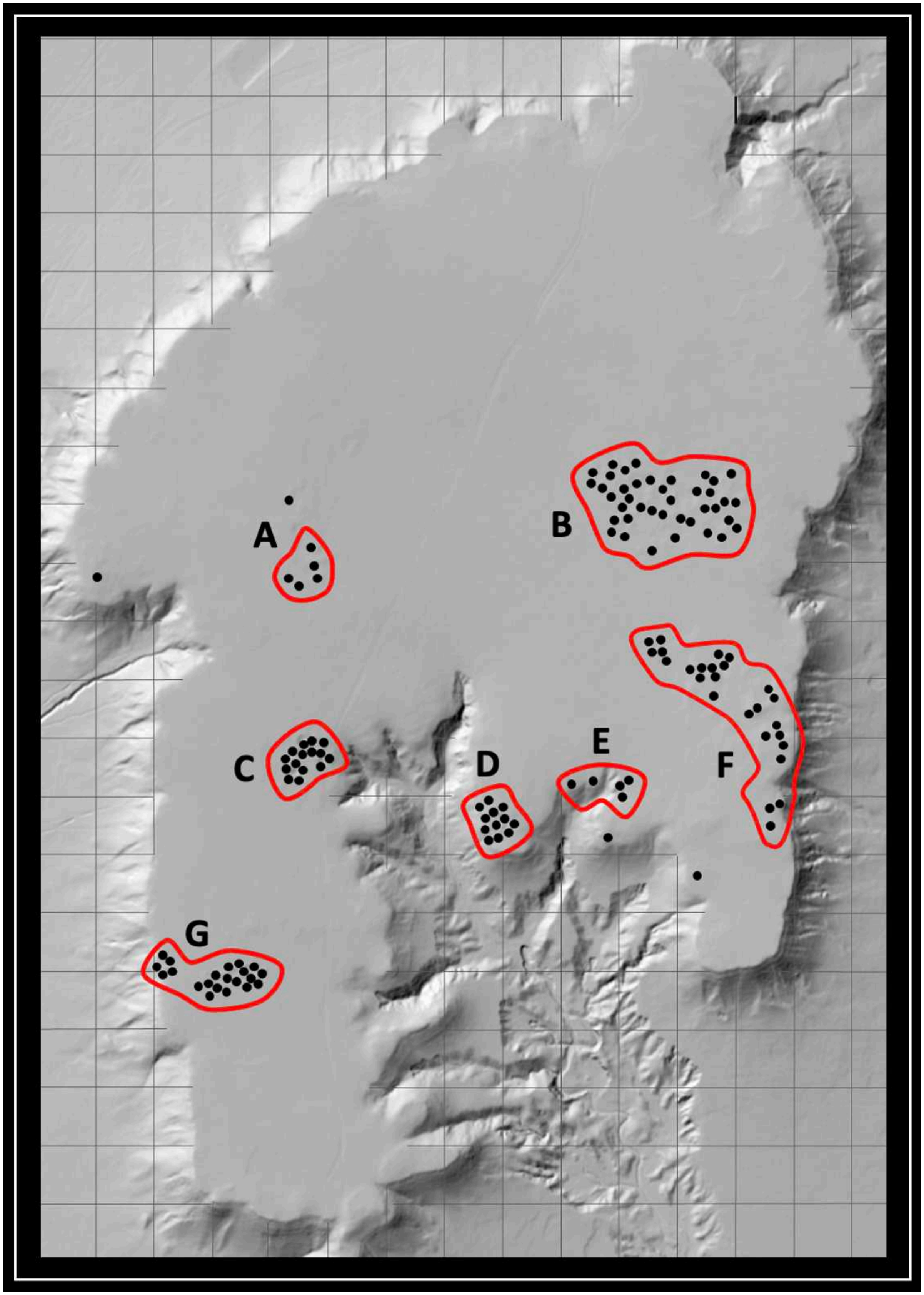

Figure 32. Location of quarry pit clusters.

CHAPTER 4 – FIELD PROJECT AND DATA RECOVERED: EXCAVATION

The excavation portion of the field projected reported here was carried out from June to September 2023. The goals of the excavation project, the methods employed, and the results obtained are reported hereafter.

Goals

As previously noted, a single 1 x 3 m excavation unit was placed in the center of a quarry pit on the surface of Flattop Butte. The goal of the excavation project was to attempt to gather data relevant to the research questions described above: site chronology, spatial organization, and mobility. With regard to site chronology, the goal was to identify and recover in-situ, dateable cultural materials in an effort to date the quarrying activity taking place in the selected pit. With regard to spatial organization, the goal was to gather and examine evidence bearing on the range of activities carried out at, in, and near the quarry pit during the acquisition of lithic raw materials. Finally, with regard to mobility, the goal was to gather evidence bearing on the time, organization, and labor required to produce useable quantities of Flattop chalcedony at the excavation location, as these factors are important inputs in the conditioning of mobility decisions.

Methods

A single quarry pit was selected for excavation testing in the center of quarry pit Cluster B (Figure 33). Cluster B was selected for three reasons. First, because it is the largest quarry pit cluster. Second, because it is a significant distance from Cluster C, where Greiser's test trench was located (Mike Toft, personal communication, 2022), allowing for a comparison of quarrying activities in different clusters. Finally, to test the hypothesis of previous investigators that quarry pits in Cluster B are more shallow than those found in other clusters because they are older, and have therefore accumulated more wind-blown loess-fill over time (Banks 1986:74; Naze 2006). The specific quarry pit in Cluster B chosen for excavation was selected because it is near the center of the cluster, and because it showed only a barely discernable surface depression, and was therefore identified on the basis of the presence of western wheatgrass.

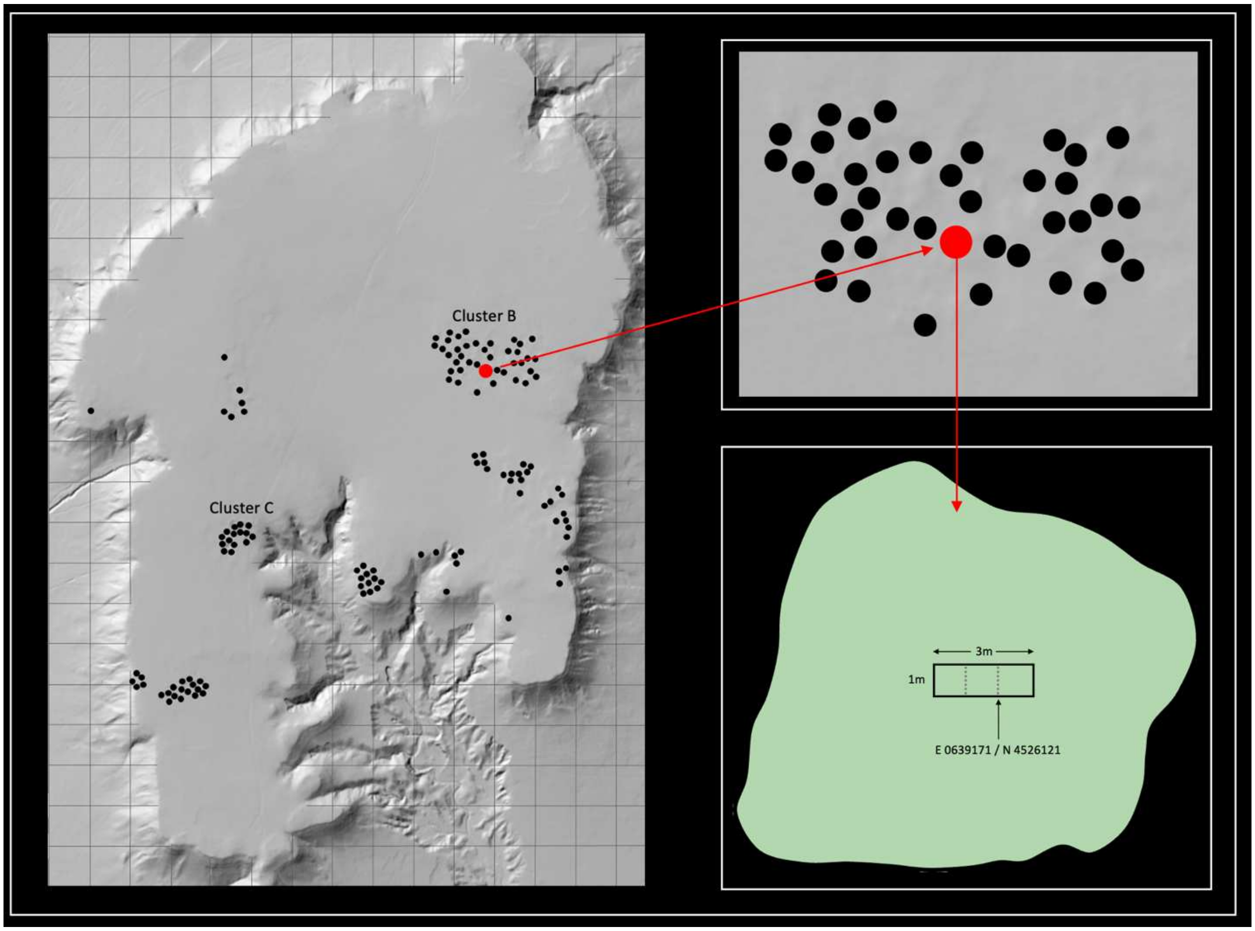

Figure 33. Location of quarry pit with excavation unit.

With a quarry pit selected, the tall western wheatgrass filling the pit areas was mowed and a location near the center of the pit was chosen. There, a 1 x 3m grid was measured and staked out on the surface on an east/west (true north) orientation, remaining vegetation was removed from the surface, and excavation commenced (Figure 34).

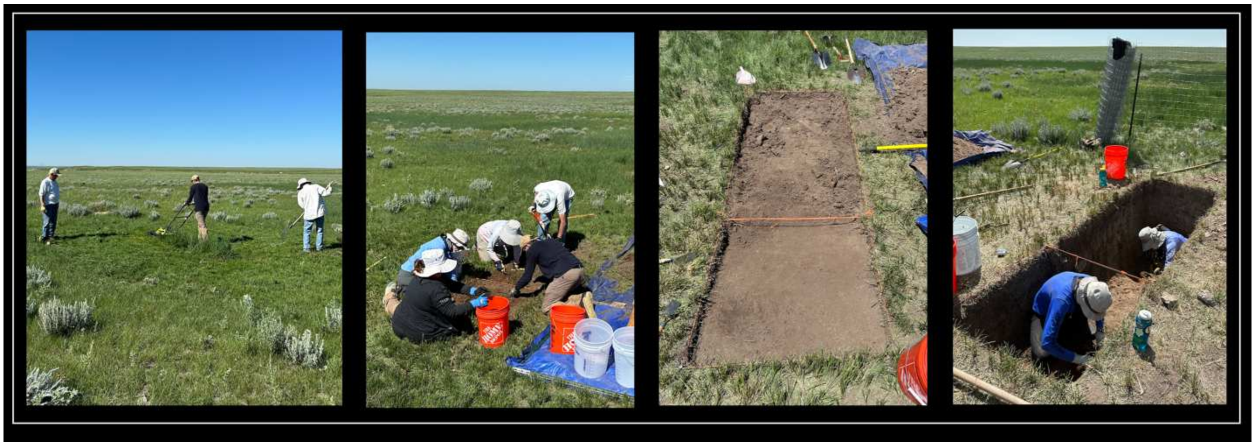

Figure 34. Preparation of excavation unit and commencement of excavation.

For purposes of excavation and analysis, the 1 x 3 m excavation unit was divided into three adjacent 1 x 1 m units (Figure 35). The easternmost unit was designated Unit A, the center unit was designated Unit B, and the westernmost unit was designated Unit C. The primary unit for analysis was Unit A. Crew members were instructed to excavate this unit in 10 cm levels and to pass the materials removed through ¼” (.64 cm) sifting screen. Units B and C were excavated primarily to expose a larger profile upon completion of the units, and therefore were without the screening of removed fill.

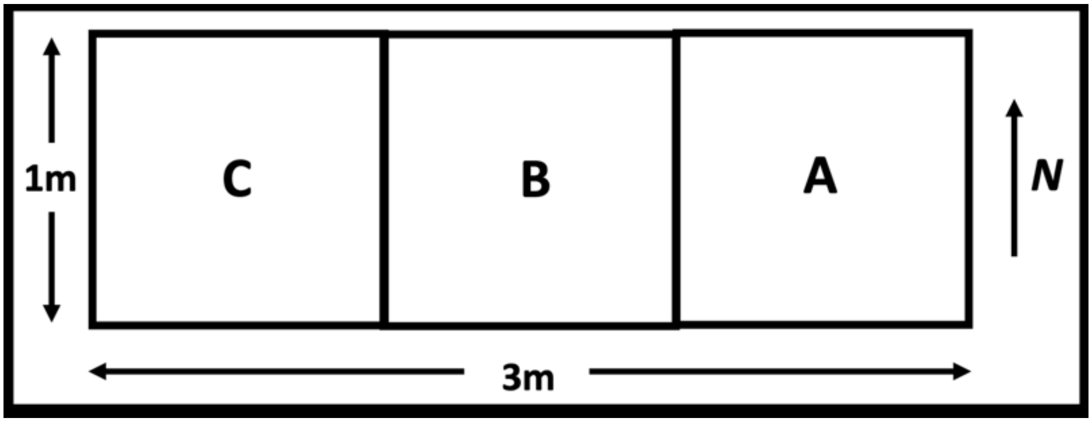

Figure 35. Excavation unit dimensions, layout, and orientation.

One purpose of the excavation project was to compare the quarrying debris present in the pit with that found by Greiser (1983) in her test trench in a quarry pit in Cluster C. As previously noted, Greiser (1983) observed that the fill in the pit was composed of soil intermixed with three types of quarrying debris: (i) flakes of chalcedony (pieces with a smooth ventral surface, removed by percussion), (ii) "chunks" of chalcedony (pieces that appeared to have been broken away from a larger mass and discarded, likely because of their small size or unusable proportions), and (iii) fractured and disturbed "slabs" of limestone (broken pieces of the caprock, with a surface area larger than 10 cm^2). Therefore, in excavating Unit A crew members were instructed to separately measure (in cm^3) the volume of each of these debris-types present in each 10 cm level.

In addition, crew members were instructed to identify and collect any finished tools, cores, hammerstones, faunal remains, or other organic material (including charcoal) located in Unit A and to note the depth at which any such object or material was found. Although materials removed from Units B and C were not screened, finished tools, cores, hammerstones, faunal remains, or other organic material (including charcoal) encountered in these units during excavation were collected, and the depth at which they were located was recorded.

Results

Unit A was excavated to a depth of 200 cm below the surface (Figure 36). At this depth, as can be seen in the north profile, excavated materials continued to contain large amounts of quarrying debris (Figure 37). As such, it was apparent that the bottom of the quarry pit (the depth at which it intersected with the chalcedony-bearing limestone caprock) had not been reached.

Figure 36. Excavation unit (photograph by the author).

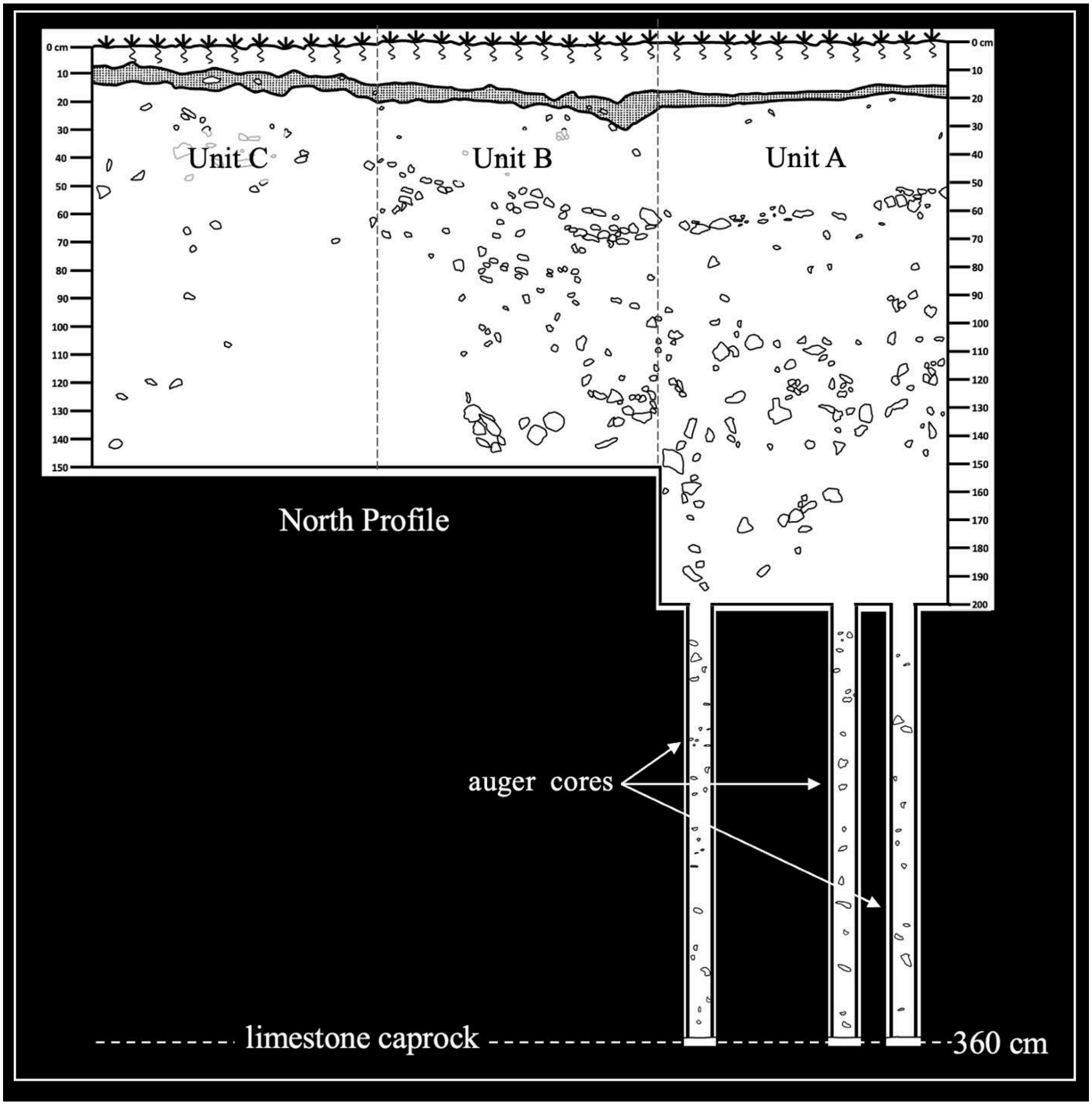

Figure 37. Drawing of north profile of excavation unit.

Therefore, to locate the bottom, a 3 ¼” (8.25 cm) bucket auger was used to remove cores from three locations at the bottom of Unit A until the underlying caprock was reached. This occurred at a depth of an additional 160 cm below the floor of Unit A, for a total depth of 360 cm from the surface to the limestone caprock[12] (Figure 37). Because of time constraints and concerns with pit wall collapse, Units B and C were excavated to a depth of only 150 cm (Figure 36).

The excavation of the 1 x 3 m unit in the selected quarry pit produced information regarding the volume and concentrations of quarrying debris in the pit fill, depth of deposits, time and labor expenditures, activities carried out in and near the quarry pit, and chronology of use. Each is discussed below.

Quarrying Debris

As the profile drawing in Figure 36 illustrates, quarrying debris – consisting of chalcedony flakes and chunks, and limestone slabs – was present in all 20 of the 10 cm levels excavated from Unit A (as well as in all levels of Units B and C), and continued to appear in auger cores until the level of the limestone caprock was reached at a total depth of 360 cm. This debris is present in the quarry pit almost certainly because it is back-fill, resulting from a common ancient quarrying method in which exhausted areas of quarry pits are refilled with the overburden and quarrying debris from newly exposed areas (Ahler and Christensen 1983:102; Frison and Stanford 1982:174).

For each 10 cm level in Unit A, this quarrying debris was measured by volume (in cm^3), separately by type, and recorded (Appendix K). Two patterns emerge from this data relating to the depth of the debris deposits and localized debris concentrations. Both are discussed below.

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[12] The conclusion that the limestone caprock had been reached at a depth of 360 cm below the surface (160 cm below the floor of excavation Unit A) was based on two observations. First, that each of the three, separately located, auger holes reached an impenetrable, seemingly smooth surface at this level. And second, that in each auger hole, a level of saturated soil was encountered at depths between 345cm and 360 cm, just above and extending to the impenetrable surface, which was interpreted as resulting from water that had drained through the quarry pit fill and was now pooling because it had reached the caprock, a semi-impermeable barrier.

Depth of Deposits and Overburden

As previously noted, quarry debris was present in all levels of all excavation units, as well as in all auger cores until the level of the limestone caprock was reached at a total depth of 360 cm. Thus, the ancient peoples who dug this quarry pit to acquire tool stone were required to remove approximately 3.6 m of top soil before reaching their target, the Flattop chalcedony-bearing limestone caprock.

The depth of the chalcedony deposits at this location are surprising. As previously noted, Greiser's 1976 test trench in a quarry pit in Cluster C found that the chalcedony-bearing limestone caprock was approximately 90 cm below the surface at that location (1983). In sharp contrast, the depth of the caprock beneath the CMPA quarry pit in Cluster B excavated here is 360 cm, four times greater than at the Greiser pit location.

This significant disparity in depth translates into a massive disparity in the effort required to quarry tool stone in these different locations. This is so because, as explained below, the four-fold increase in depth meant that the volume of overburden that had to be removed to reach the chalcedony-bearing caprock at the CMPA location was *5-15 times greater* than at the Greiser location, depending on the total area of caprock exposed.

The volume of overburden that must be removed to reach a buried target is a function of the area and depth of the target and the angle of repose of the pit walls (Figure 38). For example, to expose a 1 m^2 area of chalcedony-bearing caprock buried at a depth of approximately 3.5 m, similar to the CMPA location, a volume of soil in the shape of a 3.5 m high, 50-degree, truncated cone must be removed (Figure 38). This shape is dictated by the angle of repose of the pit walls that would be required to prevent cave-ins.[13] The total volume of soil overburden in such a truncated cone would be over 40 m^3, and it would weigh over 56 metric tons.[14] As shown in Figure 38, a pit dug in this fashion appears trapezoidal in section and circular in plan.

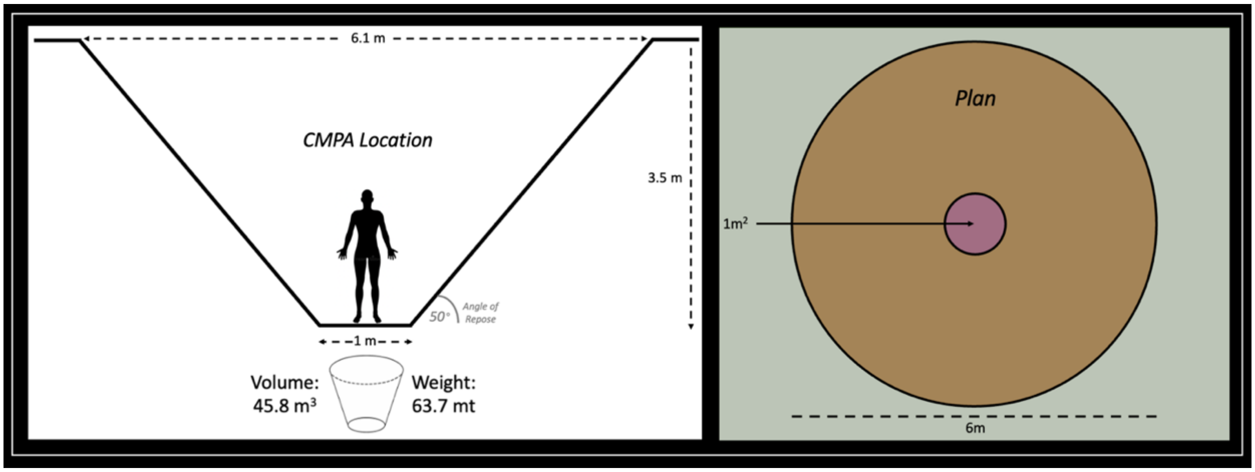

Figure 38. Section and plan views of hypothetical quarry pit, with volume and weight of overburden removed.

In comparison, the volume of overburden that would have been required to be removed at the Greiser pit location to accomplish the same task would be dramatically less. There, the caprock was buried at around a meter deep, meaning that exposing a 1m^2 area of chalcedony-bearing caprock at that location would require the removal of only around 3m^3 of soil, weighing around 4.4 metric tons, less than 7% of the overburden required to be removed at the CMPA location to expose the same area of caprock. (Figure 39).

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[13] The angle of repose on pit walls necessary to prevent a cave-in varies based on the characteristics of the surrounding soil. Federal regulations set the maximum allowable slope between 53% and 34% percent, depending on the soil type (United States Department of Labor 2024). For purposes of the calculations summarized here, a high angle of repose (50%) is used in an effort to avoid overstating the soil volumes at issue. If lower angles of repose were required, soil volumes would increase as pit walls flattened.

[14] The soil encountered in the quarry pit at the CMPA location consisted of a clay loam. Accordingly, for purposes of the calculations summarized here, an average density of 1390 kg/m^3 was used to estimate the weight of volumes of overburden removed (Structx 2024).

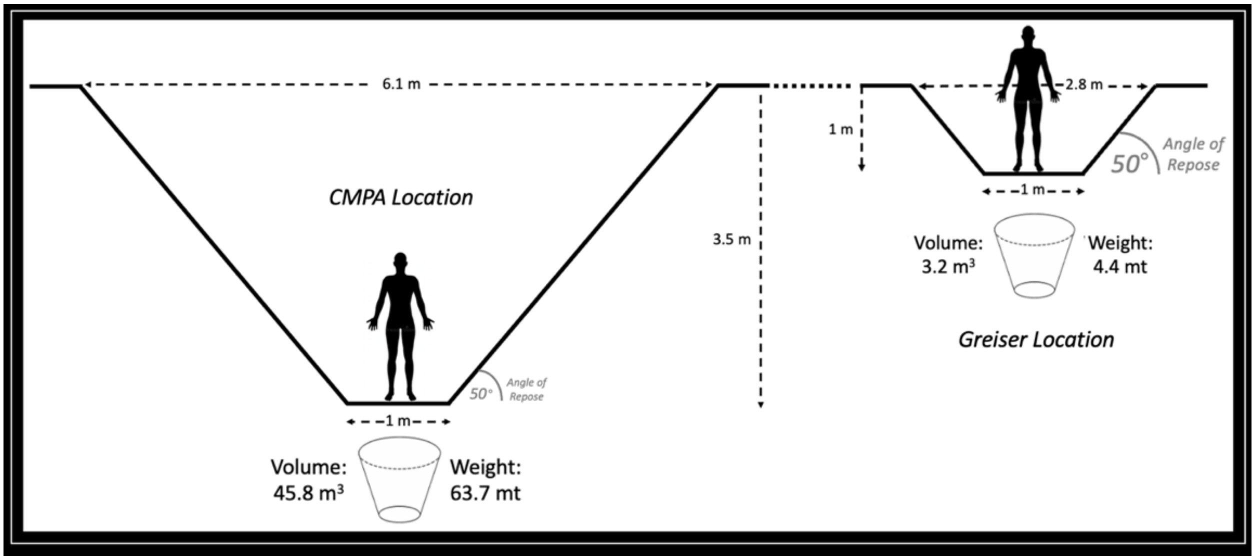


Figure 39. Comparison of overburden removal required at CMPA and Greiser locations.

Importantly, as shown in Figure 40, once a new quarry pit had reached the target depth and area of exposure, the volume of overburden that would need to be removed to expose incremental areas of the same size drops significantly. As a result, as the area of caprock exposure increases, the average volume of overburden per unit area of exposure drops, as does the relative difference in overburden between the CMPA and Greiser locations (Table 2).

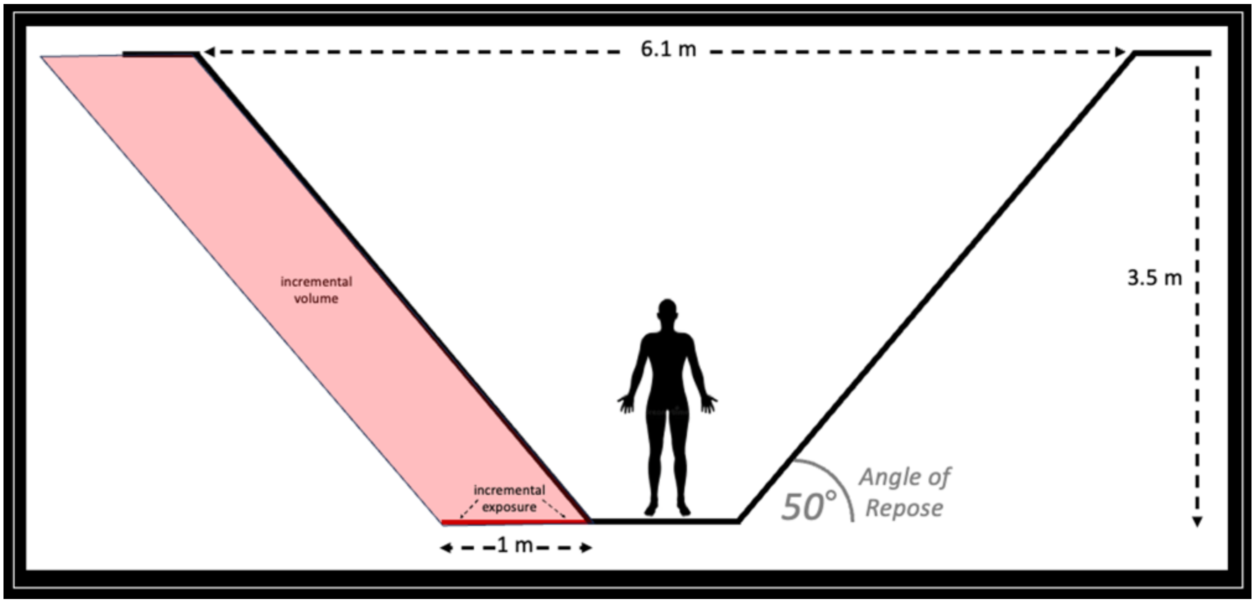


Figure 40. Illustration of incremental overburden required to expose additional unit areas of caprock.

However, as shown in Table 2, the massive disparity in overburden removal required at the CMPA versus the Greiser location persists, even when very large areas of caprock are excavated and exposed. Thus, the cost of quarrying chalcedony at the CMPA location, in time and labor, was dramatically (five to 15 times) higher than at the Greiser location.

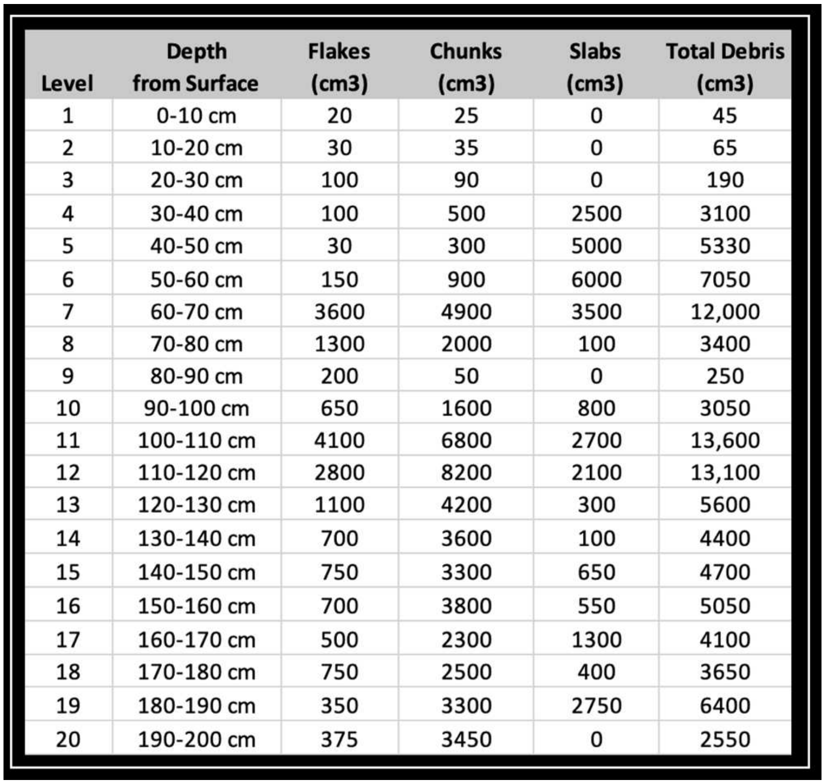
Table 2. Comparison of overburden removal required at CMPA and Greiser locations.

Area of Caprock Exposure (m^2)	Greiser Location Overburden (volume / weight)	CMPA Location Overburden (volume / weight)	Increase (multiple) at CMPA v. Greiser location
1	3.2 m^3 / 4.4 mt	45.8 m^3 / 63.7 mt	14.5 x
3	6.3 m^3 / 8.8 mt	73.6 m^3 / 102.3 mt	11.7 x
5	9.1 m^3 / 12.7 mt	89.9 m^3 / 125 mt	9.9 x
10	15.4 m^3 / 21.4 mt	124.1 m^3 / 172.5 mt	8.1 x
20	27.6 m^3 / 38.4 mt	183 m^3 / 254.4 mt	6.6 x
50	61.6 m^3 / 85.6 mt	336.9 m^3 / 468.3 mt	5.5 x

Debris Concentrations and Lenses

As previously noted, quarrying debris, consisting of chalcedony flakes and chunks and limestone slabs, were encountered in all levels of excavation Unit A. The volume of this debris, segregated by type by 10 cm level, is set forth in Table 3 and Appendix A.

Table 3. Quarrying debris by volume, segregated by type, in excavation Unit A.



Level	Depth from Surface	Flakes (cm3)	Chunks (cm3)	Slabs (cm3)	Total Debris (cm3)
1	0-10 cm	20	25	0	45
2	10-20 cm	30	35	0	65
3	20-30 cm	100	90	0	190
4	30-40 cm	100	500	2500	3100
5	40-50 cm	30	300	5000	5330
6	50-60 cm	150	900	6000	7050
7	60-70 cm	3600	4900	3500	12,000
8	70-80 cm	1300	2000	100	3400
9	80-90 cm	200	50	0	250
10	90-100 cm	650	1600	800	3050
11	100-110 cm	4100	6800	2700	13,600
12	110-120 cm	2800	8200	2100	13,100
13	120-130 cm	1100	4200	300	5600
14	130-140 cm	700	3600	100	4400
15	140-150 cm	750	3300	650	4700
16	150-160 cm	700	3800	550	5050
17	160-170 cm	500	2300	1300	4100
18	170-180 cm	750	2500	400	3650
19	180-190 cm	350	3300	2750	6400
20	190-200 cm	375	3450	0	2550

Figure 41 depicts quarrying debris volume by 10 cm level, both in total and separately by category. Flake volume is depicted in purple, chunks in red, and slabs in gray.

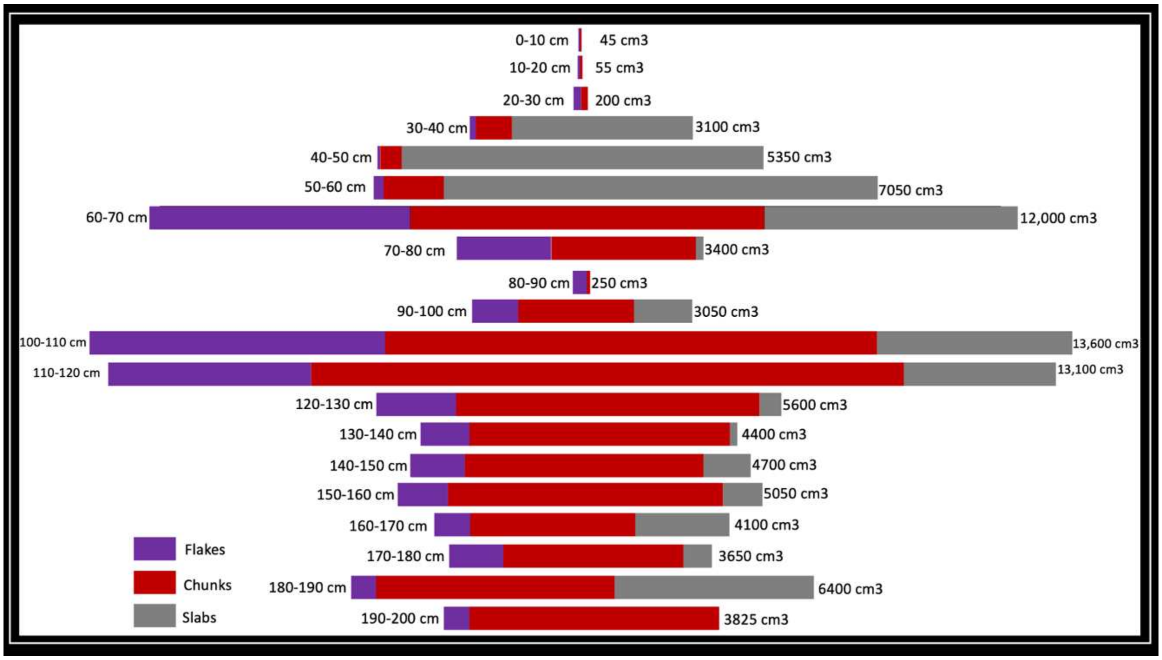


Figure 41. Quarrying debris volume by 10 cm level in excavation Unit A, segregated by debris type.

Several patterns emerge from this data. The first is simply the sheer volume of quarrying debris in the quarry pit fill. Nearly 98,000 cubic centimeters of debris, weighing over 250 kilograms[15] (560 pounds), was recovered and recorded in the 2 m^3 of fill removed from excavation Unit A.

The next notable pattern is that the quarrying debris encountered was not randomly distributed throughout the fill, but rather highly concentrated in particular levels (Figure 41). For example, 47% of the total debris recovered was concentrated in only four of the 20 levels removed from Unit A, and in each case these high concentration levels appeared in pairs, with levels 6 and 7 containing nearly 20% of the total debris, and levels 11 and 12 containing over 27%. Similarly, nearly 80% of the total debris volume was found in 10 of the 20 excavation levels.

It appears that at least some of these areas of high debris concentration may represent single-event reduction episodes in which large volumes of quarrying debris were produced and re-deposited in mass in the ancient quarry pit. For example, as shown in Figure 42 a heavy concentration of debris was encountered in excavation Unit B. This densely-packed debris lens passed through the eastern half of Unit B between 55 and 94 cm of depth, and continued into Unit A (Figure 41). Two independent lines of evidence suggest that this lens feature in Unit B may be the result of a single quarrying episode.

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[15] The amount of 2.6 grams per cm^3 is used here for purposes of calculating the weight of debris volume, based on an average of bulk densities of cherts and limestones reported in Manger (1963).

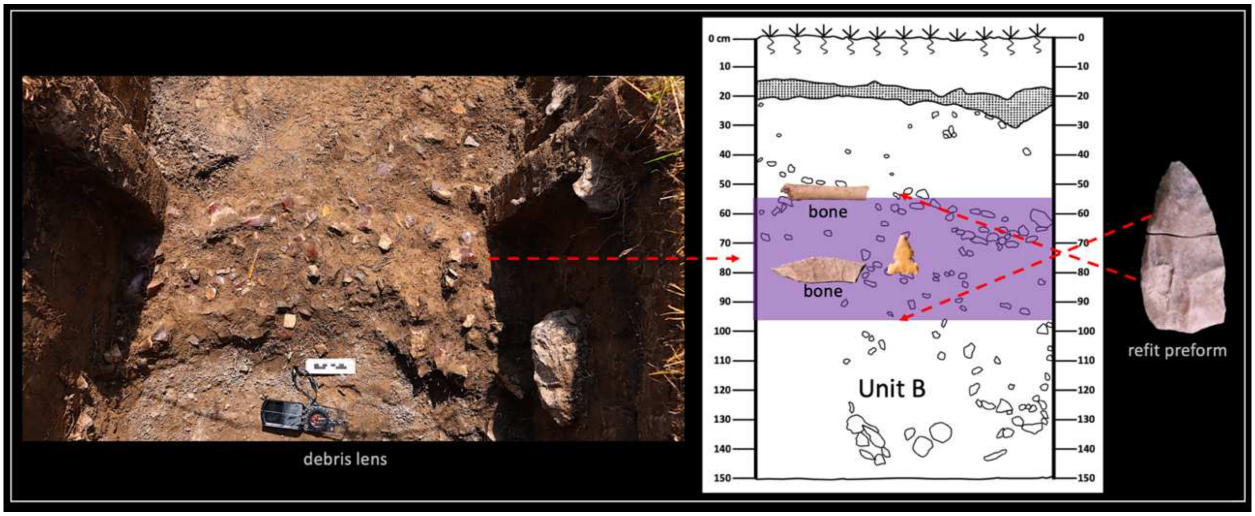

Figure 42. High-density debris lens in excavation Unit B. View from above (left) and from profile (right). Conjoined preform is shown at right (photographs by the author).

The first line of evidence relates to a broken preform. The bottom (proximal) portion of this preform was recovered at a depth of 55 cm, on top of the Unit B debris lens (Figure 42). The top (distal) portion of this preform was later recovered, at a depth of 94 centimeters, just under the bottom of the debris lens. The top and bottom portions of this preform, separated by approximately 40 cm of densely packed quarrying debris, conjoin perfectly with each other (Figure 42). The fact that the Unit B debris lens is bracketed, above and below, by halves of the same broken preform suggest that it was produced and deposited in a single episode.

In addition, dateable materials recovered in and above the Unit B debris lens also support this hypthothesis. Specifically, a bone fragment was recovered on top of the debris lens, adjacent to the preform base discussed above. A portion of this bone fragment was submitted for radiocarbon dating, a returned a calibrated (median) date of 677 years before the present (Appendix F). Twelve centimeters beneath this bone, at a depth of 67 centimeters, another piece of bone was located, most likely a fragment of the mandible of a bison (*Bison bison*). This fragment was encased in and surrounded by the Unit B debris lens (Figure 41). A portion of this second bone fragment, was also submitted for radiocarbon dating, and it returned a calibrated (median) date of

679 years before the present. These dates are well within each other's margin of error. They also match well with a temporally diagnostic, Upper Republican style arrow point recovered within the debris lens[16] (Figure 41), dateable to around 1025 to 645 calibrated years before the present AD (Eighmy and LaBelle 1996; Scheiber and Reher 2007). The fact that bone fragments with statistically matching, artifact-corroborated, dates were recovered on top of and inside the Unit B debris lens supports the suggestion that it was produced and deposited in a single episode.

It is possible that one or more of the high-density debris levels encountered in excavating Unit A were also the result of single event quarrying episodes. For example, a band of heavy debris appears in Unit A at roughly the same depth as the Unit B debris lens just discussed, suggesting that it may be part of the same, continuous debris feature (Figure 36). Similarly, the heaviest concentration of quarrying debris in Unit A is found between 100 cm and 120 cm of depth (Figure 36), suggesting the possibility that this debris concentration may also be the remains of another quarrying/backfill episode.

Finished Tools, Hammerstones, and Cores

Finished tools, hammerstones, and cores were encountered In the course of excavating Units A, B, and C, and they were subsequently collected and recorded (Appendix D). The artifacts collected in the excavation of Unit A are pictured in Figure 43, together with an illustration depicting the relative depth at which they were located. They include four hammerstones, three

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[16] The arrow point (#77) was not located during the excavation of the debris lens, but rather was recovered during an effort to screen and further examine the contents of the lens. Therefore, while it is clear that the arrow point was within the debris lens, it is unclear at what depth it originally rested.

endscrapers, two cores, two bifaces, and an abrader, with most appearing at a depth between 100 cm and 160 cm.

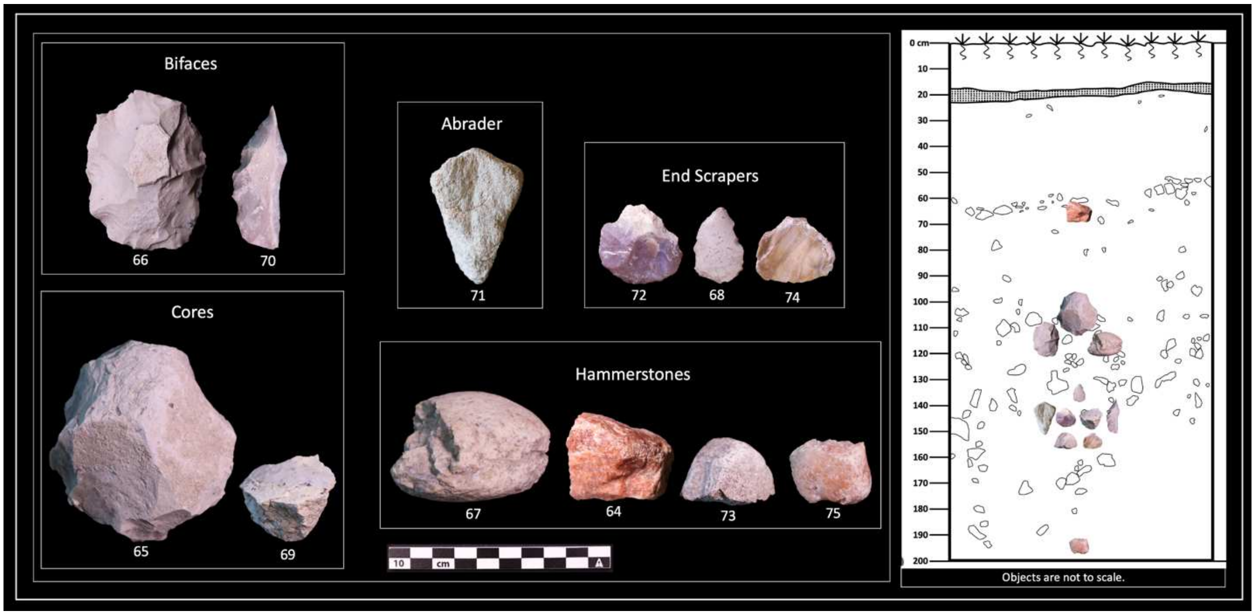

Figure 43. Finished tools, cores, and hammerstones recovered in excavation Unit A.

The finished tools, hammerstones, and cores collected in the excavation of Unit B are pictured in Figure 44, together with an illustration depicting the relative depth at which they were located. They include seven hammerstones, two bifaces, two preforms, and an arrow point, with all appearing at a depth between 50 cm and 140 cm. As previously noted, the projectile point is a temporally diagnostic Upper Republican style point, dateable to around 1025 to 645 calibrated years before the present (Eighmy and LaBelle 1996; Scheiber and Reher 2007). No finished tools, hammerstones, or cores were encountered in the excavation of Unit C.

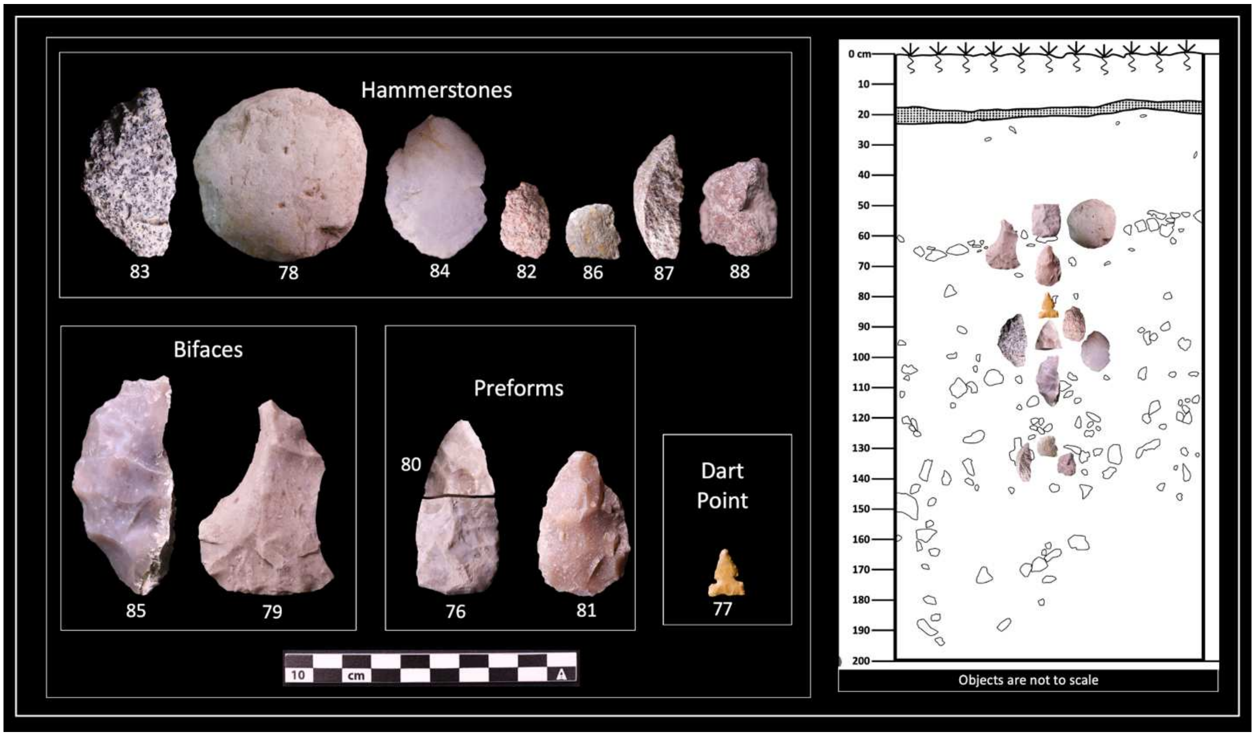

Figure 44. Finished tools and hammerstones recovered in excavation Unit B.

Exotic Materials (Non-Flattop Chalcedony)

Of the 23 finished tools, hammerstones, and cores collected in the excavation units, 12 are made of lithic materials that did not originate from Flattop Butte (Appendix E). The majority of these are hammerstones, four made of quartz (#64, #75, #78 and #84) and four made of granite (#67, #73, #82, and #83), all of unknown origin. Other exotic materials recovered in the excavation unit include: (i) a single endscraper made of a non-Flattop cryptocrystalline silicate (# 74), possibly Alibates chert from the Texas Panhandle, roughly 620 km to the southeast of Flattop Butte (Bousman et al. 2011); (ii) a single abrader made of sandstone of unknown origin (# 71); (iii) a single preform made of quartzite, possibly from the Spanish Diggings quarry in eastern Wyoming, 280 km to the northwest of Flattop Butte (Reher 1991); and (iv) a single arrow point made of Smoky Hill silicified chalk (# 77), which outcrops in stream drainages in southwest Nebraska and northwest Kansas, roughly 275 km to the southeast of Flattop Butte (Stein 2005). A map of the locations of possible sources of the exotic materials recovered in the survey and excavation project appears at Figure 24.

Faunal Remains

Faunal remains, consisting of 165 bone fragments were recovered in excavation Units A and B, and near the bottom of one of the auger cores beneath the floor of Unit A , at depths between 30 cm and 340 cm (Appendix J). None were recovered in Unit C. The various depths at which bone fragments were recovered is illustrated in Figure 45.

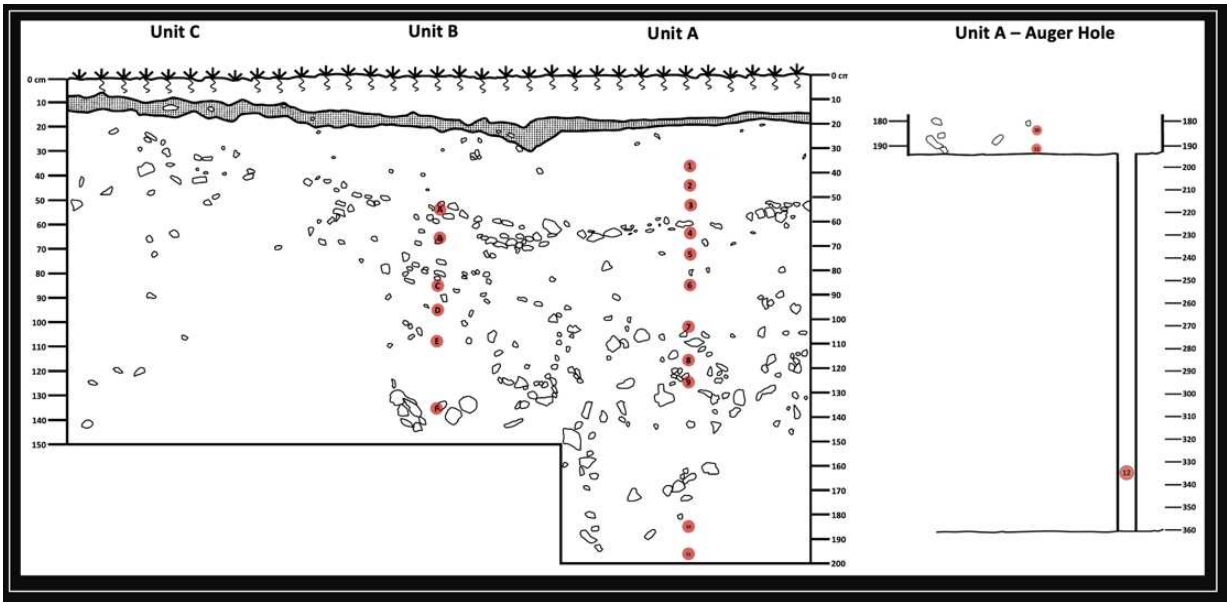

Figure 45. Depths at which bone specimens were recovered in excavation Units A and B.

Of these 165 bone fragments, 13 are sufficiently intact and diagnostic for taxonomic identification (Appendix I)[17]. Six of the fragments appear to be from a large, immature canid, most likely a gray wolf (*Canis lupus*) (Figure 45). These bones, likely from a single individual, were

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[17] The taxonomic identifications reported here were carried out by Alex Pelissero, doctoral candidate in biological anthropology at Colorado State University.

recovered in excavation Unit A between a depth of 40 and 44 cm. They include three humerus fragments (A,D, and E), two of which (D and E) conjoin, two radius fragments (B and C), and one ulna fragment (J) (Figure 46).

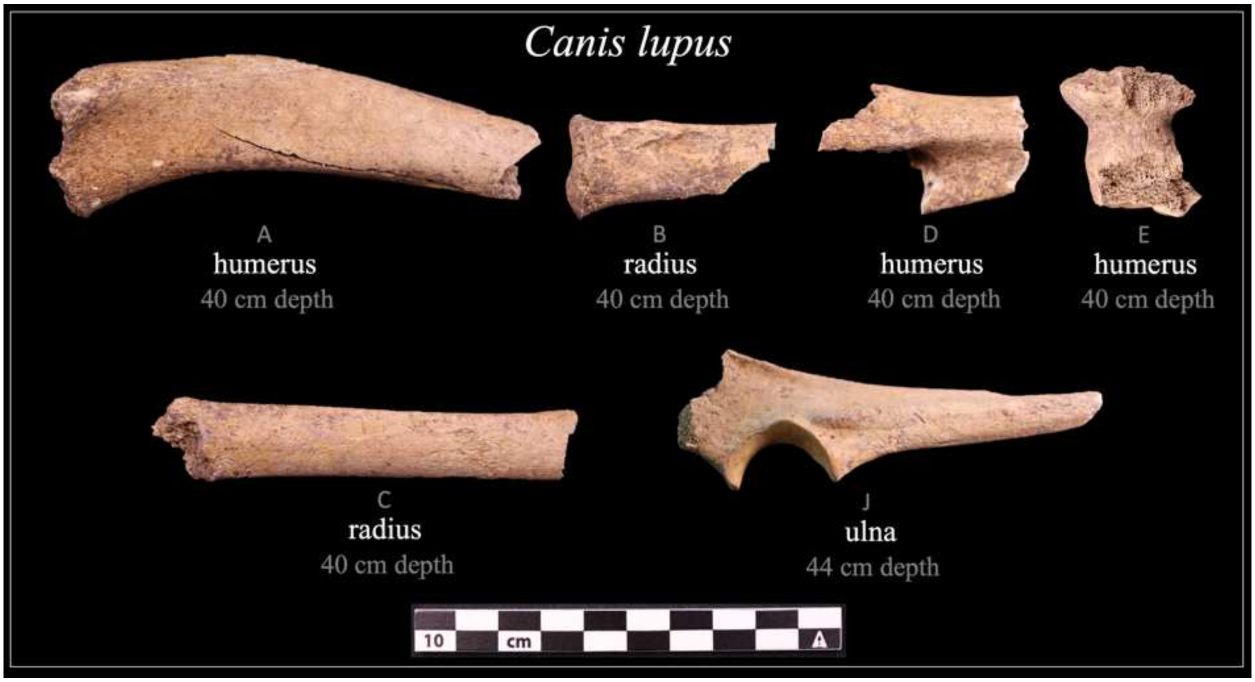

Figure 46. Diagnostic bone fragments of *Canis lupus* recovered in excavation Unit B.

The other seven diagnostic bone fragments appear to be from one or more bison (*Bison bison*) (Figure 47). Three of the bison fragments were recovered in excavation Unit A at depths between 71 cm and 83 cm, and include a pelvis fragment (L), an eye socket fragment (M), and the head of a femur (N) (Figure 46). The remaining four fragments were recovered in Unit B at depths between 67 cm to 132 cm, and include a mandible fragment (H), a phalanx (G), and two rib fragments (O,P) (Figure 47).

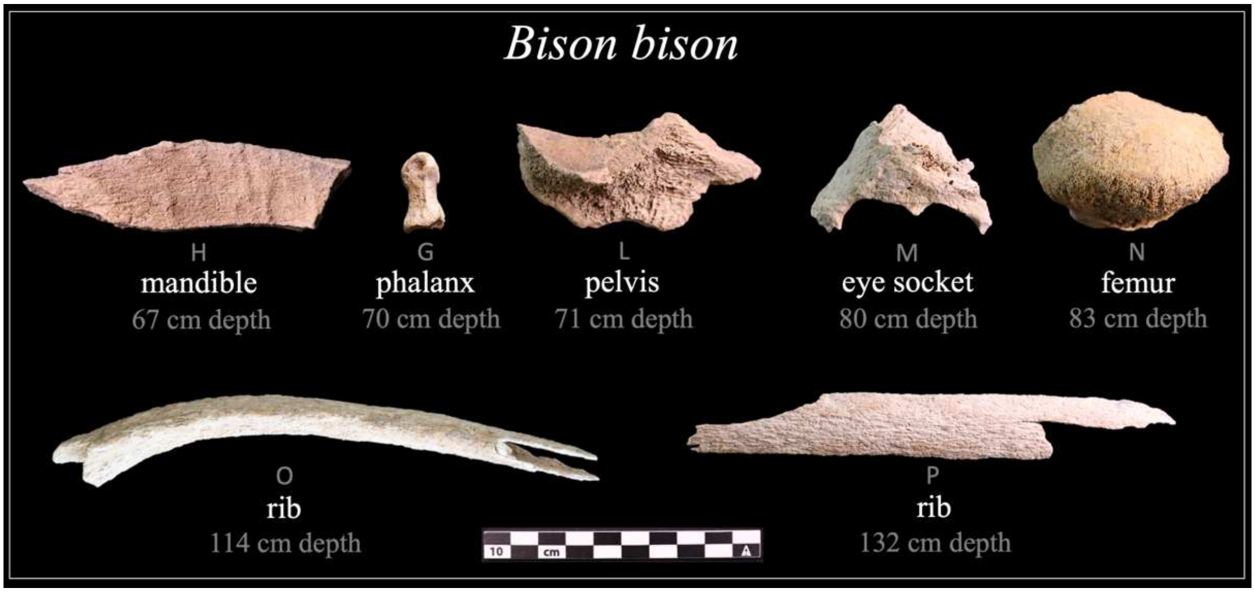

Figure 47. Diagnostic bone fragments of *Bison bison* recovered in excavations Unit A and B.

Charcoal

Forty-two small pieces of charcoal were recovered in excavation Units A and B. None were recovered in Unit C. The depths at which charcoal samples were recovered is depicted in Figure 48. The unit, depth, and number of samples are recorded in Appendix K.

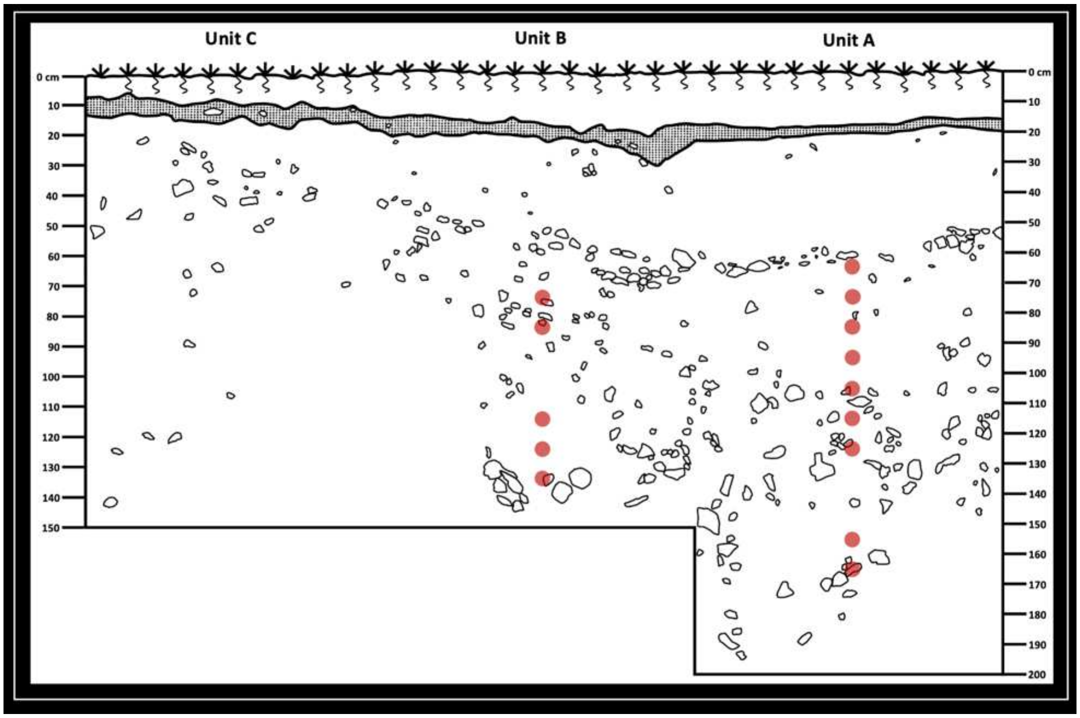

Figure 48. Depths at which charcoal specimens were recovered in excavation Unit A and B.

Radiocarbon Dating

Nine of the 165 bone fragments recovered in excavation Units A and B were submitted for radiocarbon dating. The depth, unit, and dates (calibrated and uncalibrated) returned for these bone fragments are shown in Table 4.

Table 4. Radiocarbon dates for bone recovered in excavation Units A and B.

Excavation Unit	**Level**	**Depth Below Surface(cm)**	**C14 Date**	**Calibrated Years Before Present (BP)[18]**	**UGA Lab ID #**
A	4	40	620 + 20 rcybp	553 cal. BP	1
B	6	55	790 + 20 rcybp	677 cal. BP	2
A	6	60	710 + 20 rcybp	649 cal. BP	5LO34-8
B	7	67	800 + 20 rcybp	679 cal. BP	3
A	12	110-120	870 + 20 rcybp	794 cal. BP	4
B	14	132	830 + 20 rcybp	684 cal. BP	5LO34-7
A	18	170-180	740 + 25 rcybp	695 cal. BP	5LO34-9
A	20	195	1200 + 20 rcybp	1066 cal. BP	5
A	auger	330-340	880 + 20 rcybp	795 cal. BP	6

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[18] Calibrated radiocarbon dates reported herein were derived using the OxCal 4.4 software (Bronk Ramsey 2009) and the IntCal20 calibration curve (Reimer et al. 2020) at a 95.4% probability.

The depth, unit, and median calibrated dates returned for these bone fragments are illustrated in Figure 49. The detailed laboratory reports for these radiocarbon dates are set forth in Appendix F.

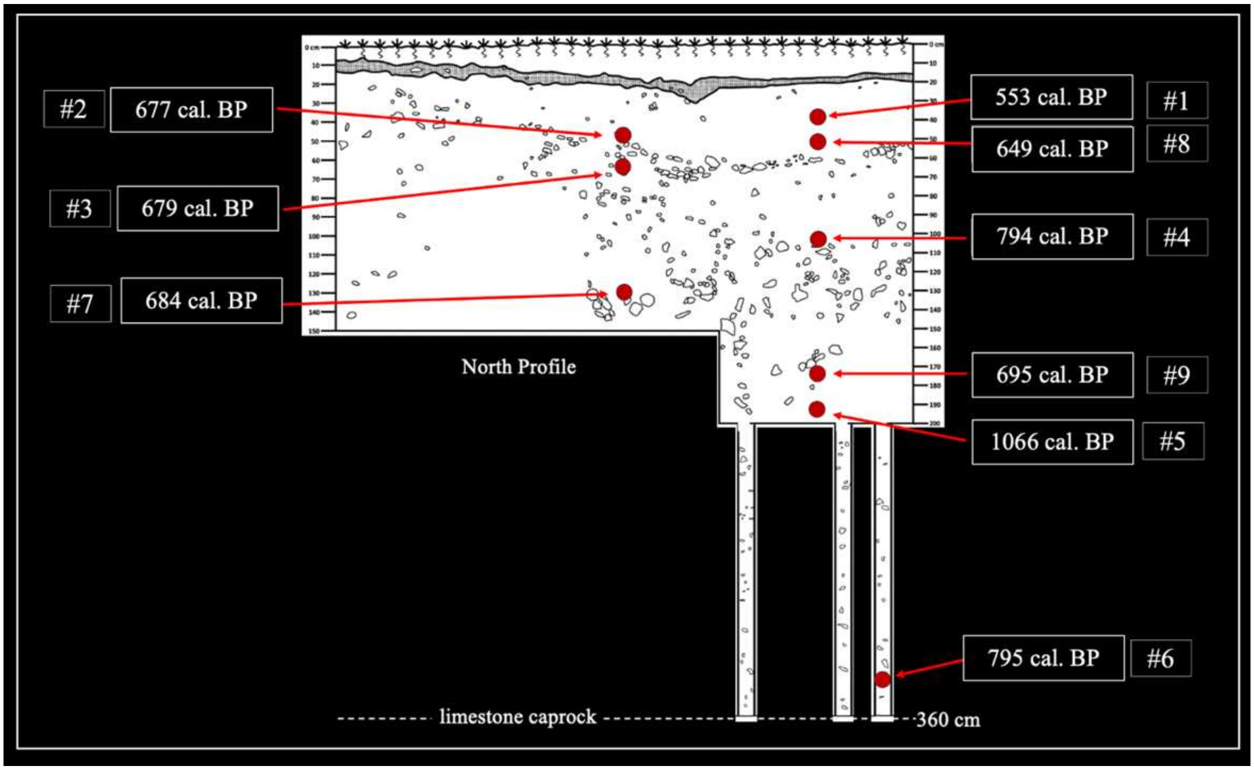

Figure 49. Calibrated radiocarbon dates for bone recovered in excavation Units A and B.

CHAPTER 5 – CHRONOLOGY OF USE

The first two research questions posed in this study relate to chronology, and ask: (i) in what periods was Flattop Butte used as a lithic source; and (ii) at what times were different areas of the site in use? Data relevant to each of these questions are discussed in turn below.

When was Flattop Butte used as a lithic raw material source?

Quarry sites such as Flattop Butte are unusual in that the great majority of information regarding when they were exploited by ancient peoples as a source of raw materials is typically found away from, rather than at, the site location itself. At the site, dating presents special problems because of the relative scarcity of dateable materials typically recovered at quarries, the enormous quantities of production debris that appear at these locations, and the necessarily disturbed, and often mixed context of these materials resulting from repeated procurement activity episodes occurring over long periods (Ahler 1986:32-37; Frison and Stanford 1982:174; Fritz 2021). In contrast, quarried lithic materials from identifiable source locations appear with regularity off-site, at dateable locations or in the form of temporally diagnostic tools, which in both cases can provide direct evidence of the time period in which the source quarry was in use.

Accordingly, in answering the question of when Flattop Butte was used as a lithic source by ancient groups, reliance will be placed in significant part on off-site appearances of Flattop chalcedony in temporally diagnostic form or at dateable locations, although on-site evidence developed in the survey and excavation carried out here will also be discussed.

Off-site Evidence: Flattop Chalcedony in the Archaeological Record

In order to track the use of Flattop Butte as a lithic source through time, a literature review using electronic databases (EBSCO, eHRAF Archaeology, Google Scholar, JSTOR, and ProQuest). was conducted searching for reports of Flattop chalcedony appearing in dated archaeological assemblages. The results of this review, including site name, cultural affiliation, calibrated date, and distance from Flattop Butte, are displayed in Table 5.[19]

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[19] References for the sites listed in Table 5 appear in Appendix L.

Table 5. Sites with assemblages including Flattop chalcedony.

Map #	Site Name	State	Period	Culture	Calibrated Date BP
2	CW	CO	Paleoindian	Clovis	13,050-12,750 BP
3	Dent	CO	Paleoindian	Clovis	13,050-12,750 BP
4	Diskau	KS	Paleoindian	Clovis	13,050-12,750 BP
5	Eckles	KS	Paleoindian	Clovis	13,050-12,750 BP
6	Frost	CO	Paleoindian	Clovis	13,050-12,750 BP
7	Drake	CO	Paleoindian	Clovis	13,050-12,750 BP
8	Kanorado	KS	Paleoindian	Clovis	13,050-12,750 BP
9	Agate Basin	WY	Paleoindian	Folsom	12,845-12,255 BP
10	Folsom	NM	Paleoindian	Folsom	12,845-12,255 BP
11	Johnson	CO	Paleoindian	Folsom	12,845-12,255 BP
12	Lindenmeier	CO	Paleoindian	Folsom	12,845-12,255 BP
13	Nolan	NE	Paleoindian	Folsom	12,845-12,255 BP
14	Hahn	CO	Paleoindian	Folsom	12,845-12,255 BP
15	Powars I	CO	Paleoindian	Folsom	12,845-12,255 BP
16	Laird	KS	Paleoindian	Dalton	12,680-10,400 BP
17	Frazier	CO	Paleoindian	Agate Basin	12,500-11,500 BP
18	Jones Miller	CO	Paleoindian	Hell Gap	11,570 BP
19	Goff Creek	OK	Paleoindian	Plainview	11,820-11,200
20	Clary Ranch	NE	Paleoindian	Allen	10,580-8550
21	Blackfoot Cave	CO	Paleoindian	Allen	10,580-8550
22	Slim Arrow	CO	Paleoindian	Allen	10,580-8550
23	Seedorf	CO	Paleoindian	Allen	10,580-8550
24	Frasca	CO	Paleoindian	Cody	10,290 BP
25	Claypool	CO	Paleoindian	Cody	10,000-8000 BP
26	Lutes	CO	Archaic	McKean	6800-2800 BP
27	Dipper Gap	CO	Archaic	McKean	3454 BP
28	Rattllesnake Shelter	CO	Archaic	?	3560-1820 BP
29	Kaplan-Hoover Bison Bonebed	CO	Archaic	Yonkee (?)	2759 BP
30	Valley View	CO	Late Prehistoric	Plains Woodland	1920-1120 BP
31	Signal Butte	NE	Late Prehistoric	Central Plains Tradition	1100-600 BP
32	West Stoneham	CO	Late Prehistoric	Plains Woodland	1060-630 BP
33	Donovan	CO	Late Prehistoric	Upper Republican	1000-700 BP
34	Medicine Creek Valley	NE	Late Prehistoric	Upper Republican	900-650 BP
35	Easterday II	CO	Late Prehistoric	Upper Republican	900-650 BP
36	Hosick	NE	Late Prehistoric	Upper Republican	900-650 BP
37	Smiley Rockshelter	CO	Late Prehistoric	High-Plains Upper Republican	900-650 BP
38	Buick	CO	Late Prehistoric	High-Plains Upper Republican	900-650 BP
39	Barnes	CO	Late Prehistoric	High-Plains Upper Republican	900-650 BP
40	Leary	NE	Late Prehistoric	Oneota	760-560 BP
41	Roberts Ranch Buffalo Jump	CO	Protohistoric	Ute	360-340 BP

A total of 40 archaeological sites, from six states, were located, spanning the entire period of known human activity in the Central Plains, from more than 13,000 years before the present, to the abandonment of the use of stone tools in the centuries after European contact (Table 5). A map illustrating the locations of these sites, appears as Figure 50.

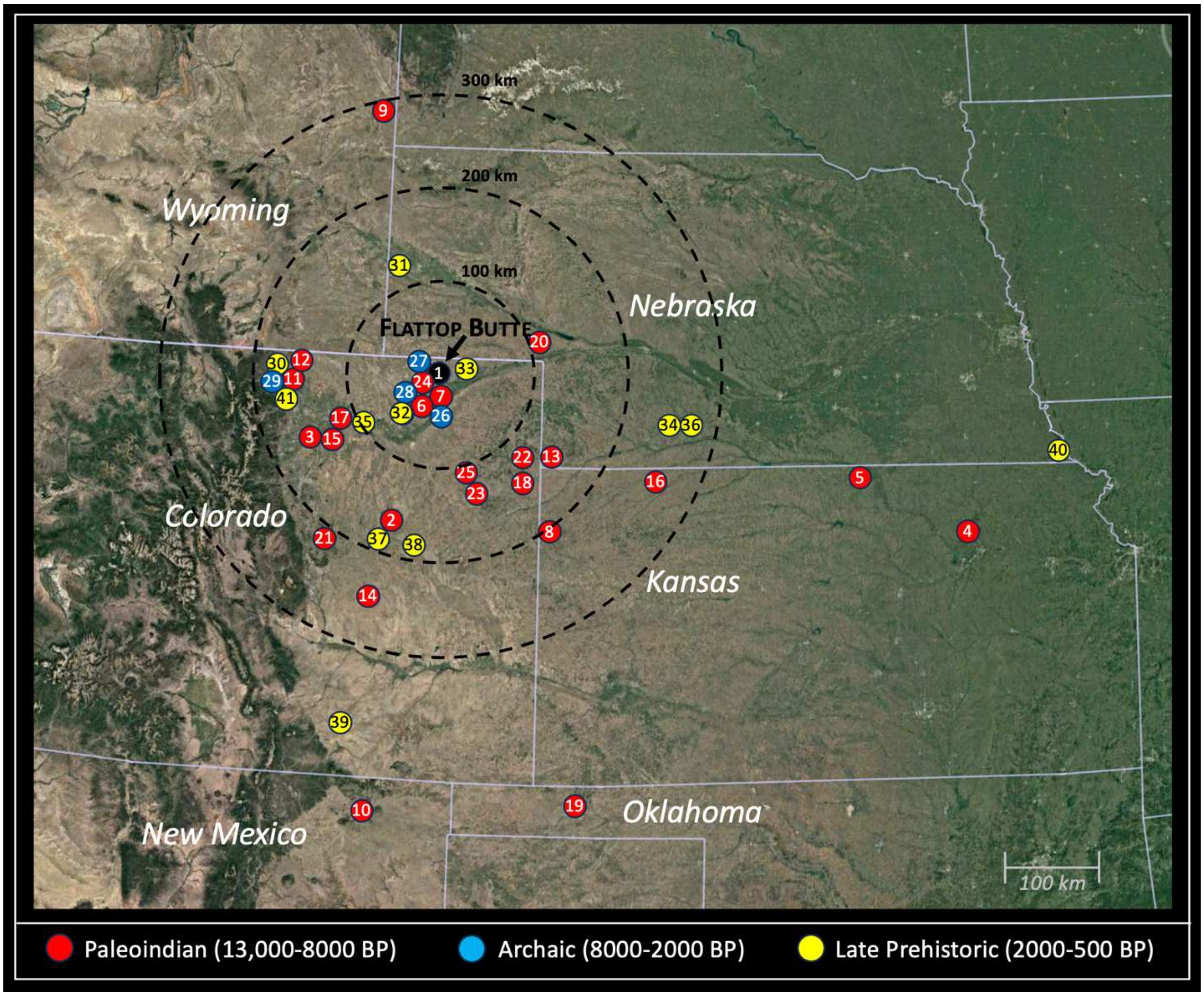

Figure 50. Location of sites with assemblages including Flattop chalcedony.

Before further analysis, it is import to note some important factors that would tend to suppress these results and cause them to be under-representative of the actual use of Flattop chalcedony in the Central Plains. First, public lands are sparse in this region, meaning that a significant source of professional archaeological investigations (those on public lands and/or mandated by state and federal regulations) are fewer and farther between here than in other regions. Next, many of the archaeological investigations that are conducted in the area are carried out on a contract basis by cultural resource management (CRM) firms, meaning that in most cases results are not published in journals or other readily available forums, and therefore would not be captured by the literature review conducted here.[20]

Finally, because this literature review sought out reports of the raw material sources of lithic material found in archeological assemblages, sites that were investigated and reported before the mid-1970's will likely not be captured, even if Flattop chalcedony was present in their assemblages.[21] This is so because the investigation of lithic sourcing, and consequently the analysis and reporting of raw material sources in site reports, was not common before this time. Despite these limitations, the results of the literature review described here do provide useful insight into the use of Flattop chalcedony over time in the Central Plains from the Paleoindian period through the Late Prehistoric period, and are discussed hereafter.[22]

Paleoindian Period Sites

Paleoindian period sites, dating from roughly 13,000 to 8,000 years ago, account for 24 of the 40 off-site appearances of Flattop chalcedony identified in the literature review (Table 5). These sites extend over an area approximately 530,000 km^2, extending north/south from the high Plains of Wyoming to the southern plains of New Mexico and Oklahoma, and east/west from the Missouri River in eastern Nebraska to the foothills of the Rocky Mountains in Central Colorado (Figure 51).

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[20] LaBelle et al. (2021) includes an excellent discussion of the numerous factors that have led to the under-reporting of archaeological sites in northeastern Colorado as compared to other regions.

[21] For example, Wood (1967) is an example of a seminal, detailed local report of archaeological sites in northeast Colorado that mentions the widespread appearance of purple chert in assemblages, but does not identify Flattop chalcedony by name or identify its source.

[22] Flattop chalcedony has also been reported at 12 undated locations, mostly lithic scatters or low-density tool collations, in the Pawnee Buttes region of Weld County, Colorado, around 50 km west of Flattop Butte (Black 2017:Table 9).

They are associated with eight identifiable cultural complexes: Clovis, Folsom, Dalton, Hell Gap, Plainview, Allen, Agate Basin, and Cody (Table 5).

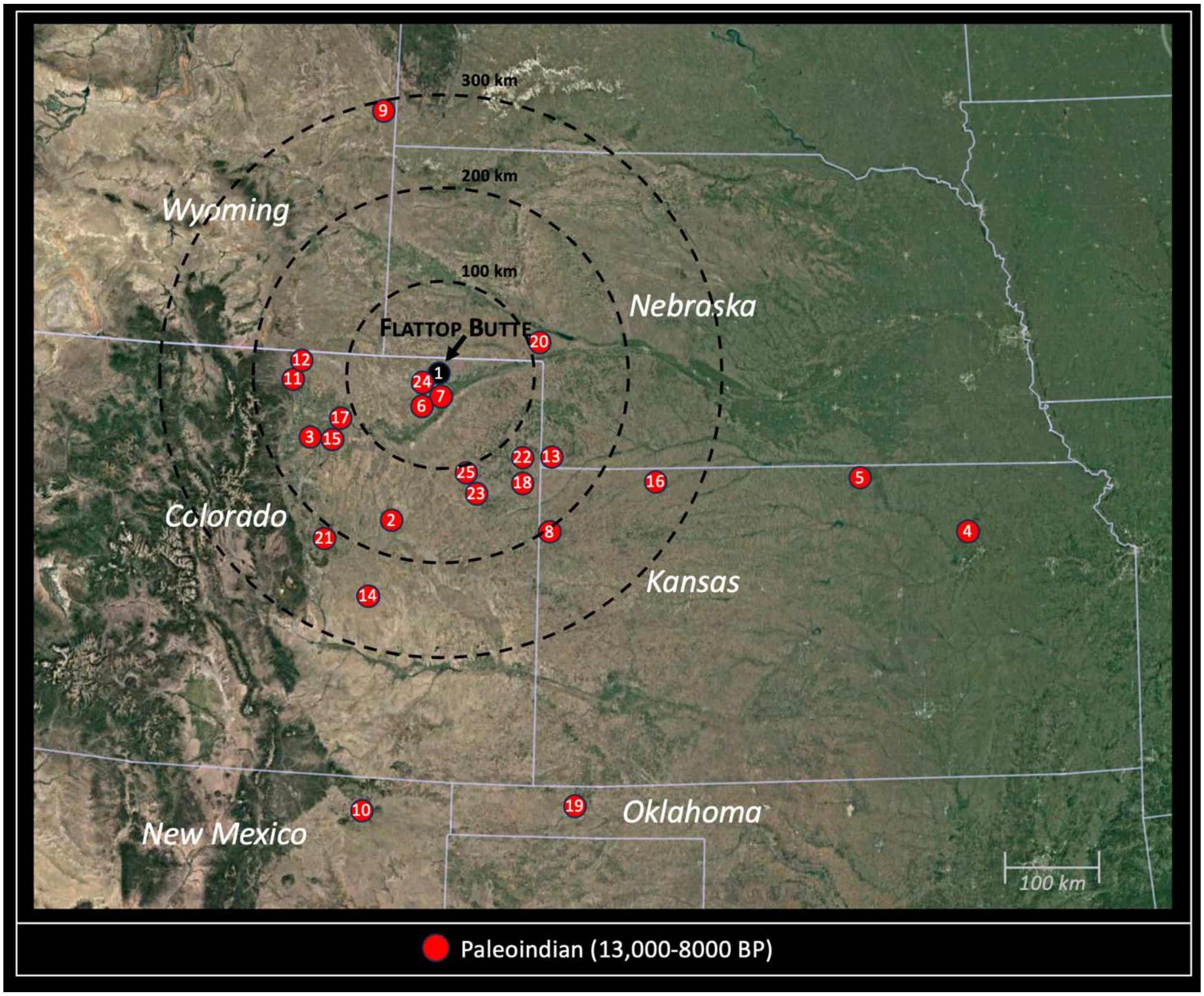

Figure 51. Location of Paleoindian period sites with assemblages including Flattop chalcedony.

Seven of these 24 Paleoindian sites are associated with the Clovis complex, dated to around 13,050 to 12,750 calibrated years before the present (Waters et al. 2020), the earliest clearly discernable and firmly dated human groups currently identified in the Central Plains[23] (LaBelle

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[23] Although evidence of possible pre-Clovis human occupation in the Central Plains has been offered for a number of sites (consisting primarily of Pleistocene mega-fauna remains with fracture patterns argued to have resulted from human action) there is no consensus among Paleoindian archaeologists regarding the accuracy of these claims (LaBelle 2012).

2012). The importance of Flattop chalcedony to Clovis groups operating in the Central Plains has been confirmed by large-scale studies of Clovis artifacts in museum and private collections by Asher (2015) and Holen (2001, 2014) who examined over 600 diagnostic Clovis projectile points and preforms originating in the Central Plains. These studies revealed that Flattop chalcedony was the most commonly used raw material employed by Clovis groups in the region for crafting these tools, accounting for around 22% of all such artifacts (Asher 2015:107; Holen 2014). These findings led Holen to suggest that Clovis groups in the Central Plains may have congregated near Flattop Butte in the early fall to acquire lithic raw materials for their upcoming trips to wintering localities, and that such aggregations would have been important opportunities for the exchange of information, rare commodities, and mates between the small bands (2001:214-217).

Five of the 24 Paleoindian period assemblages with Flattop chalcedony artifiacts identified in the present literature review are associated with the post-Clovis, Folsom complex (Table 5), dated to around 12,845 to 12,255 calibrated years before the present (Buchanan et al. 2021). Asher's (2015) study of Paleoindian raw material usage in the Central Plains confirms the continued importance of Flattop chalcedony to the Folsom groups. Of 606 Folsom projectile points, preforms, and channel flakes[24] from the Central Plains examined by Asher, 31 percent (n=169) were found to be made of Flattop chalcedony, more than twice the number of any other material (Asher 2015:107-108).

The 10 remaining Paleoindian period sites with artifacts made of Flattop chalcedony are associated with the Dalton, Hell Gap, Plainview, Allen, Agate Basin, and Cody complexes. These

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[24] Channel flakes are long, thin flakes removed from the base of projectile points during their manufacture, creating a distinctive groove or channel on one or both sides of the point. "Fluted" points with such channels are diagnostic of Clovis and Folsom assemblages.

groups were active in the Central Plains from between 12,685 to 8,000 calibrated years before the present (Table 5).

Taken together, the 24 Paleoindian period sites identified in the literature review demonstrate that Flattop Butte was consistently visited and exploited as a source of lithic raw materials by human groups throughout this period (Table 5). Moreover, these sites demonstrate that throughout the Paleoindian period Flattop chalcedony was regularly transported over long distances from its source, including to locations 305 km to the north, 480 km to the south, and 580 km to the east of Flattop Butte (Figure 50). This evidence, when combined with the evidence that Flattop chalcedony was the most commonly used material for preforms and projectile points in the Central plains among Clovis and Folsom groups (Asher 2015; Holen 2014), paints a picture of Flattop Butte as a critical resource hub throughout the Paleoindian period, drawing groups travelling over long distances seeking essential, high-quality, lithic raw materials.

Archaic Period Sites

Archaeological assemblages including Flattop chalcedony are far more limited in the succeeding Archaic period, around 8000 to 2000 years before the present (Figure 52). Only four sites were identified in the literature review, and the time span they represent is narrow.

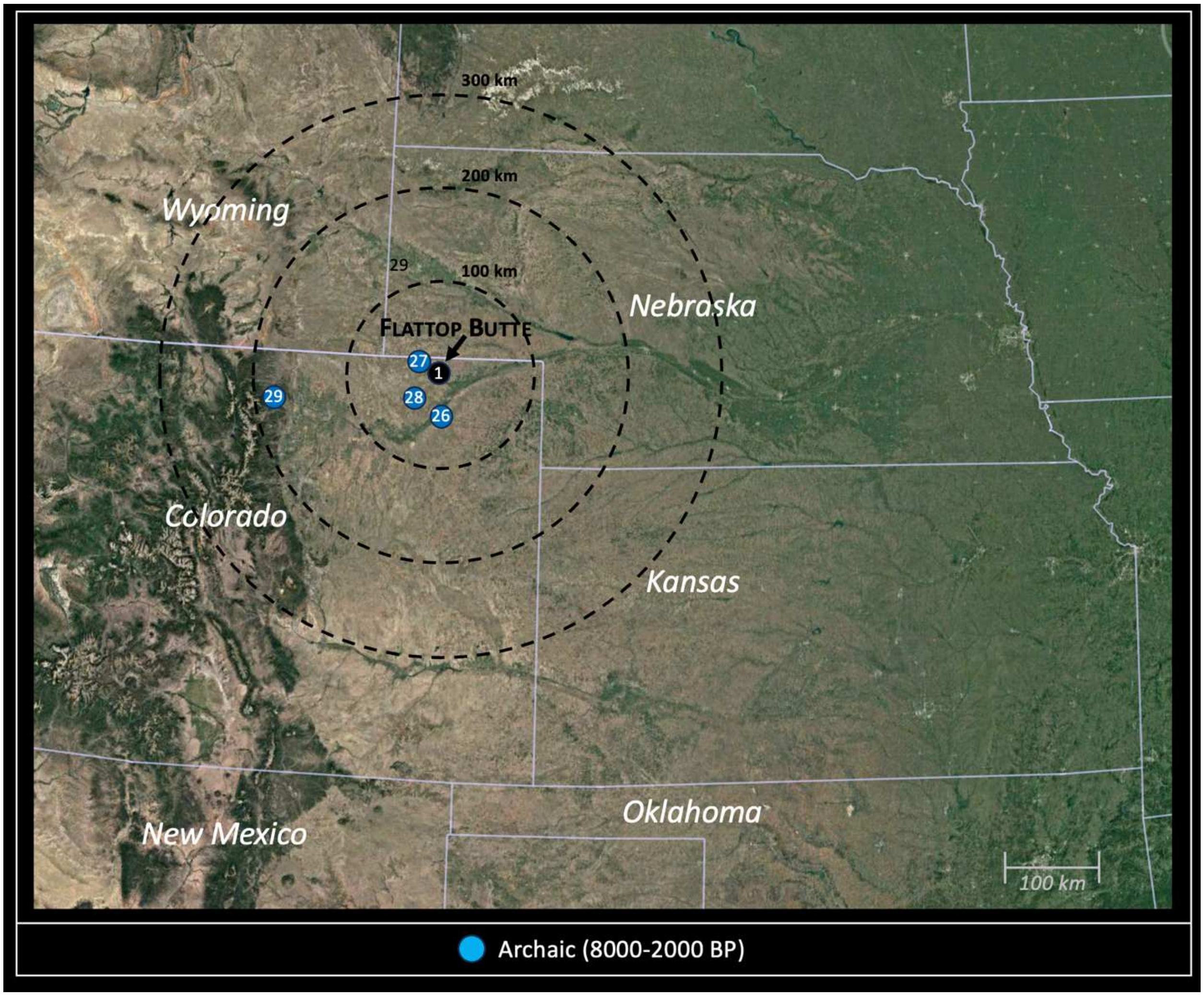

Figure 52. Location of Archaic period sites with assemblages including Flattop chalcedony.

At the Dipper Gap site, Flattop chalcedony was the dominant material used over a long period of time, but only beginning in the latter third of the Archaic period, from and after around 3500 calibrated years before the present (Metcalf 1974:184-185). The Lutes site is a burial of two individuals (LaBelle et al. 2013). Its assemblage includes four temporally diagnostic, McKean Complex projectile points made of Flattop chalcedony, which are said to resemble the dominant point type at the nearby Dipper Gap site "in every detail" (LaBelle et al. 2013). While McKean points of this type were in use in the Central Plains from around 5700 to 2250 calibrated years before the present (Eighmy and LaBelle 1996), the resemblance of the McKean points found at

Lutes to those from Dipper Gap, which is less than 55 km away, suggests that Lutes likely also dates to the latter third of the Archaic period.

The Rattlesnake Shelter site is a short-term, seasonal campsite with evidence of multiple stays associated with bison hunting spanning the Late Archaic period from 3560 to 1820 calibrated years before the present (Brunswig 1996:270). A single biface made of Flattop chalcedony was found in its assemblage (Brunswig 1996:276). Finally, the Kaplan-Hoover site is a bison bone-bed site, dated to 2759 (median) calibrated years before the present, with three dart points made of Flattop chalcedony in its assemblages (Todd et al. 2001).

These four Archaic period sites with Flattop chalcedony are limited not only in number and time, but also in space. Three of the four sites, Dipper Gap, Lutes, and Rattlesnake Shelter, are located less than 50 km from Flattop Butte and within 55 km of each other (Figure 52). The area formed by these three locations (473 km^2) covers less than 1/10 of 1% of the area in which Flattop chalcedony appeared in archaeological assemblages in the preceding Paleoindian period (529,250 km^2). The sole outlier, the Kaplan-Hoover bison bone-bed, is 150 km to the west of Flattop Butte, suggesting some long-distance transport of Flattop chalcedony in the Late Archaic period. However, the assemblage contains only three dart points and no other tools or debitage made of Flattop chalcedony, suggesting the movement of only curated tools rather than entire assemblages from Flattop Butte to the site.

The apparent drop in the use of Flattop chalcedony in the Central Plains in the Archaic period reflected here is likely somewhat misleading. Private collections in the region contain many examples of Late Archaic period artifacts, many of which are made of Flattop chalcedony, that are not captured by the literature review reported here (LaBelle et al. 2021; Mike Toft, personal communication 2023).

Moreover, the absence of sites with Flattop chalcedony in the Early Archaic period is not altogether surprising, in that it mirrors a similar decline in the number of all archaeological sites in the region at this time. As one prominent chronicler of the Great Plains has described the period between around 8000 and 4000 years before the present, “the archaeological record appears to be largely lacking in sites” (Wedel 1986:72). The cause of this scarcity is widely (but not unanimously) attributed to a period of limited or highly transitory human presence in the region caused by a climate event known as the Altithermal, which brought drier and warmer conditions to the region resulting in marked declines in surface water, ground water, precipitation, and critical resources, including bison[25] (Meltzer 1999; Wedel 1986:72). Importantly, most stone tool assemblages recovered in the Great Plains during this period are composed largely of locally available raw materials, suggesting a significant reduction in mobility as compared to the prior Paleoindian period (Meltzer 1999).

Late Prehistoric Period Sites

The record of Flattop chalcedony use during the Late Prehistoric period, between approximately 2000 and 500 years before the present, represents a return to a pattern of widespread use and transportation as seen in the Paleoindian period (Figure 53). Twelve of the 40 assemblages identified in the literature review are from Late Prehistoric period (Table 5).

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[25] It has also been suggested that the decline in Archaic period sites in the Great Plains is due not only to harsher climate conditions, but also to a bias in sampling caused by the amount of erosion and deposition in this period that removed or deeply buried sites of this age (Meltzer 1999; Reeves 1973).

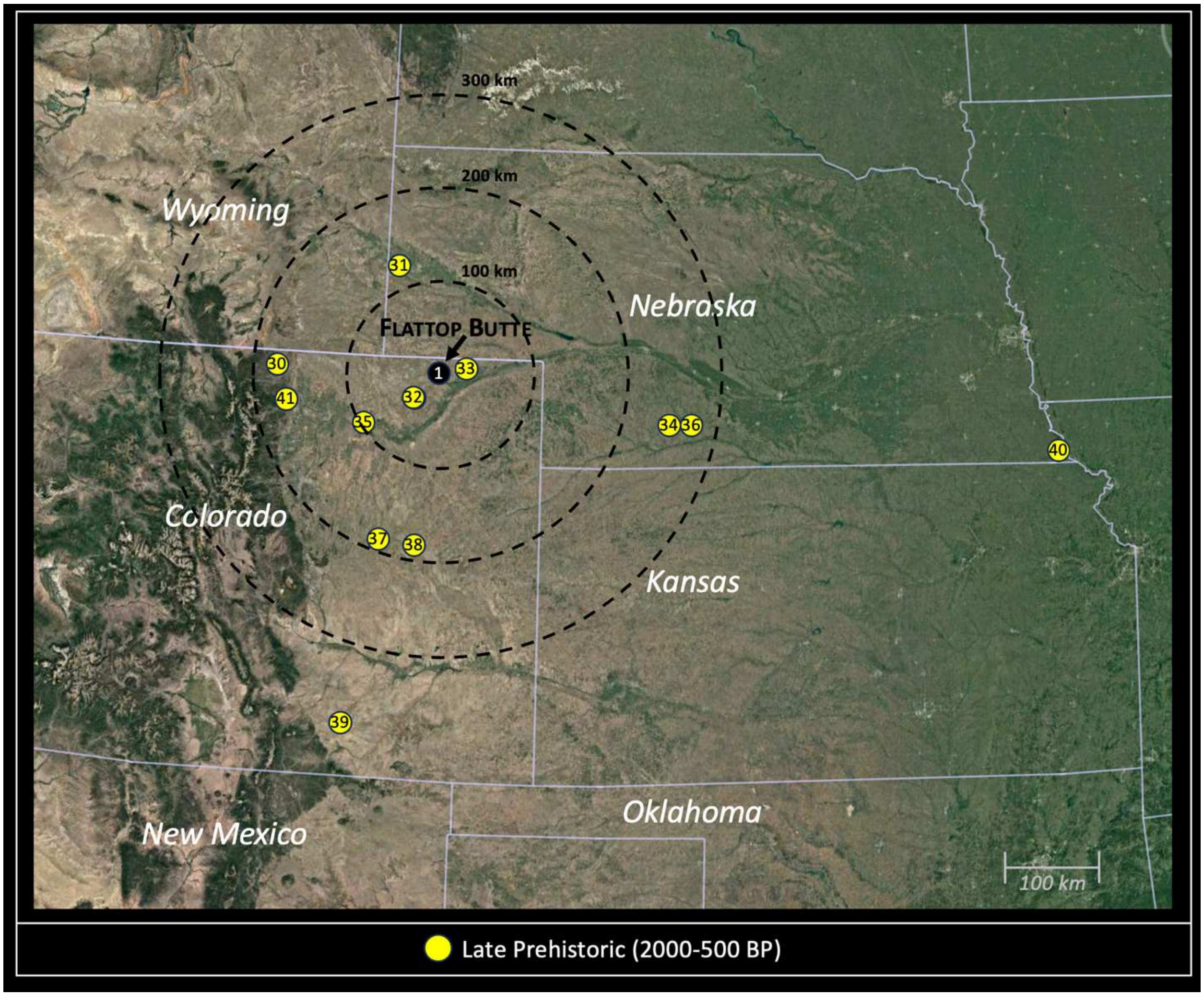

Figure 53. Location of Late Prehistoric period sites with assemblages including Flattop chalcedony.

These sites extend over an area approximately 400,000 km^2, extending north/south from west-Central Nebraska to the south-Central Colorado, and east/west from southeast Nebraska to the foothills of the Rocky Mountain in northern Colorado (Figure 52). They are associated with six identifiable cultural complexes: Plains Woodland, Central Plains Tradition, Upper Republican, High-Plains Upper Republican, Oneota, and Ute (Table 5).

In addition to the individual sites identified here, Wood (1967) recorded extensive utilization of a “purple chert,” likely Flattop chalcedony, by Late Prehistoric, Upper Republican groups operating over long distances in and around northeastern Colorado. Similarly, Wedel recorded widespread use of Flattop chalcedony by Upper Republican groups in south-Central Nebraska between 1100 and 600 calibrated years before the present (1986:111).

On-Site Evidence: Diagnostic Tools and Radiocarbon Dates

The evidence gathered on-site at Flattop Butte in the course of the survey and excavation work described above, while not as detailed, corroborates the picture painted by the literature review of use of the site as a lithic source from the Paleoindian period through the Late Prehistoric period. This evidence consists of : (i) three diagnostic projectile points, and (ii) ten radiocarbon dates, one from a thermal feature and the remaining nine from bone recovered at various levels in an excavated quarry pit.

The three diagnostic projectile points span from the Paleoindian period to the Late Prehistoric period. The first is the base of a Paleoindian, Agate Basin point (Figure 54-30), dating to between around 12,500 and 11,500 calibrated years before the present (LaBelle 2005:Table 2.1). The second is the base and mid-section an Archaic period, Duncan-Hanna dart point (Figure 54-37), dating to between 5700 and 2250 calibrated years before the present (Eighmy and LaBelle 1996). The third diagnostic projectile point is a complete Late Prehistoric, Upper Republican style arrow point (Figure 54-77), dating to between 900 and 650 calibrated years before present (Wedel 1986).

Figure 54. Diagnostic projectile points.

The ten radiocarbon dates obtained in this project are from two locations. The first is a buried thermal feature found eroding from the south-center edge of the butte (Figure 58). Organic material on a sample of burned rock from this feature returned a date of 2700-2600 calibrated years before the present (Appendix F). The other nine dates were from bone recovered at a variety of depths in an excavation unit in a quarry pit in Cluster B, at the east-Central portion of the butte (Figure 48). These radiocarbon dates range from around 1066 to 553 median, calibrated years before the present (Table 4, Figure 48), with five of the dates clustering between 649 and 695 calibrated years before the present, and two others falling between 794 and 795 calibrated years before the present. These dates are consistent with the diagnostic arrow point recovered at a depth of between 55 and 94 cm in the Unit B of the excavation unit (Figure 20-77), associated with Upper Republican groups operating in the vicinity of Flattop Butte around 1000 to 700 calibrated years before the present (Scheiber and Rehr 2007).

Overview

Taken together, the off-site evidence of Flattop chalcedony appearing in assemblages of dated archaeological contexts, and the time-diagnostic projectile points and radiocarbon dates recovered on-site, paint a picture of Flattop Butte being visited and exploited as a source of lithic raw materials from more than 13,000 years before the present to the abandonment of stone tools in the centuries after European contact. While it appears that the quarrying and use of Flattop chalcedony rose and fell over time, the evidence gathered here demonstrates that Flattop Butte remained a consistent source of essential lithic resources for the entire period of known prehistoric human activity in the Central Plains.

When were different locations on Flattop Butte in use?

In contrast to the wealth of information discussed above regarding the periods in which Flattop Butte was visited by ancient peoples and exploited as a lithic source, data regarding when specific locations on the butte were employed is sparse. Indeed, before the present investigation, no date associated with any location on the butte had been obtained and published. As illustrated in Figure 55, the survey and excavation work conducted here identified four locations with associated dates.

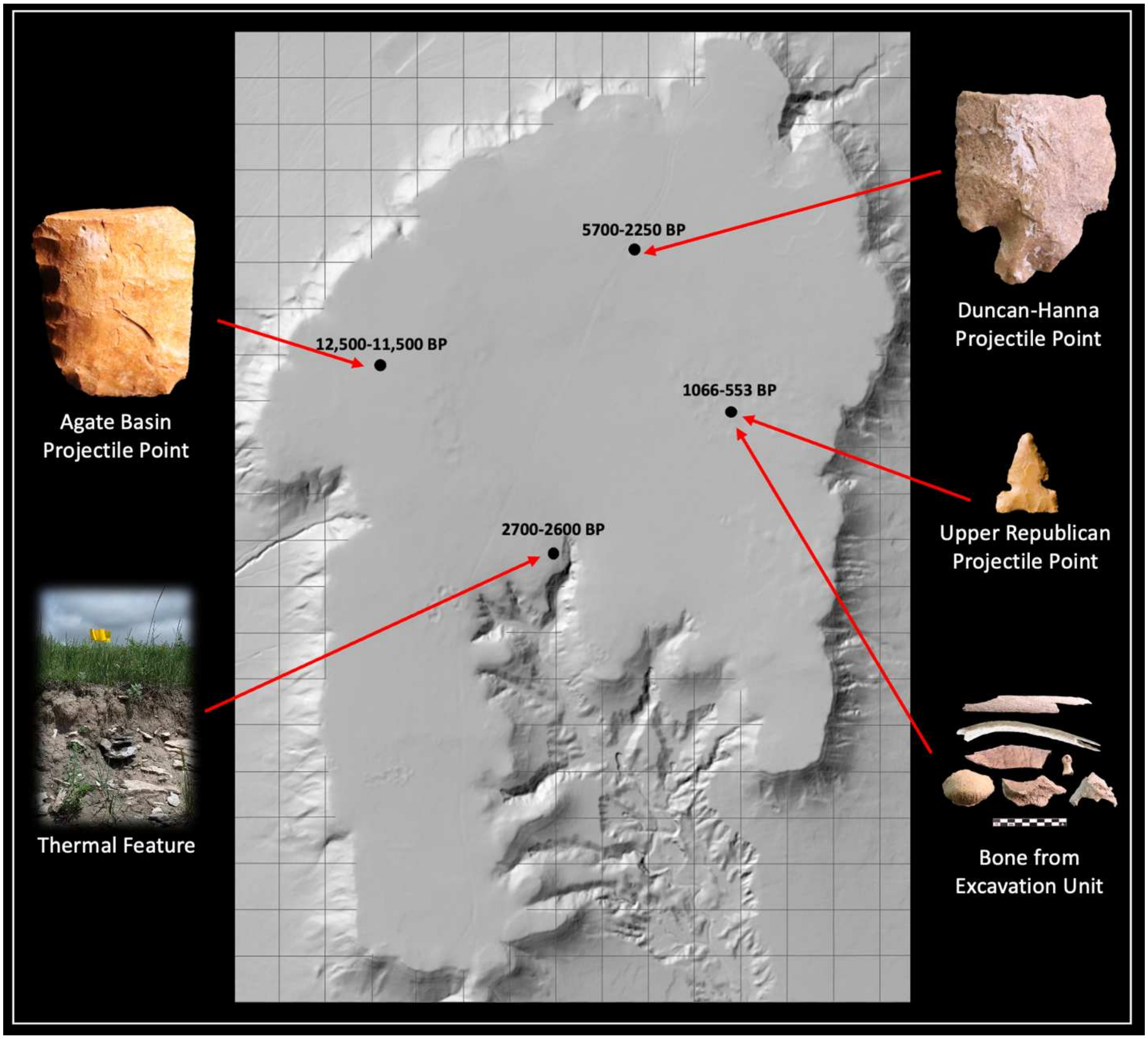

Figure 55. Dated locations on Flattop Butte.

The first such location is in the west-Central portion of the butte. There a diagnostic Paleoindian period, Agate Basin projectile point dating to between 12,500 and 11,500 calibrated years before present was recovered . The second location is in the north-Central portion of butte. There a diagnostic Archaic period, Duncan-Hanna dart point dating to between 5700 and 2250 calibrated years before the present (Eighmy and LaBelle 1996) was recovered. The third location is on the edge of an erosional wash in the center portion of the butte. There a buried thermal feature was identified and radiocarbon dated to the Late Archaic period, between 2700 and 2600 calibrated years before the present. The final location is in the east-Central portion of the butte. There an excavation unit in a quarry pit yielded a diagnostic, Late Prehistoric, Upper Republican arrow point, and nine radiocarbon dates from bone, all dating to between 1066 to 553 calibrated years before the present. Each location is discussed in more detail below.

Paleoindian Period Locations

The Paleoindian period, Agate Basin, projectile point was found in the center 1 m^2 of a high-density debris area in survey unit 91, roughly 75 meters from a quarry pit, and 125 m from quarry pit Cluster A (Figure 55). It was surrounded by around 800 cm^3 (2.1 kg) of chalcedony flakes and chunks (Figure 56).

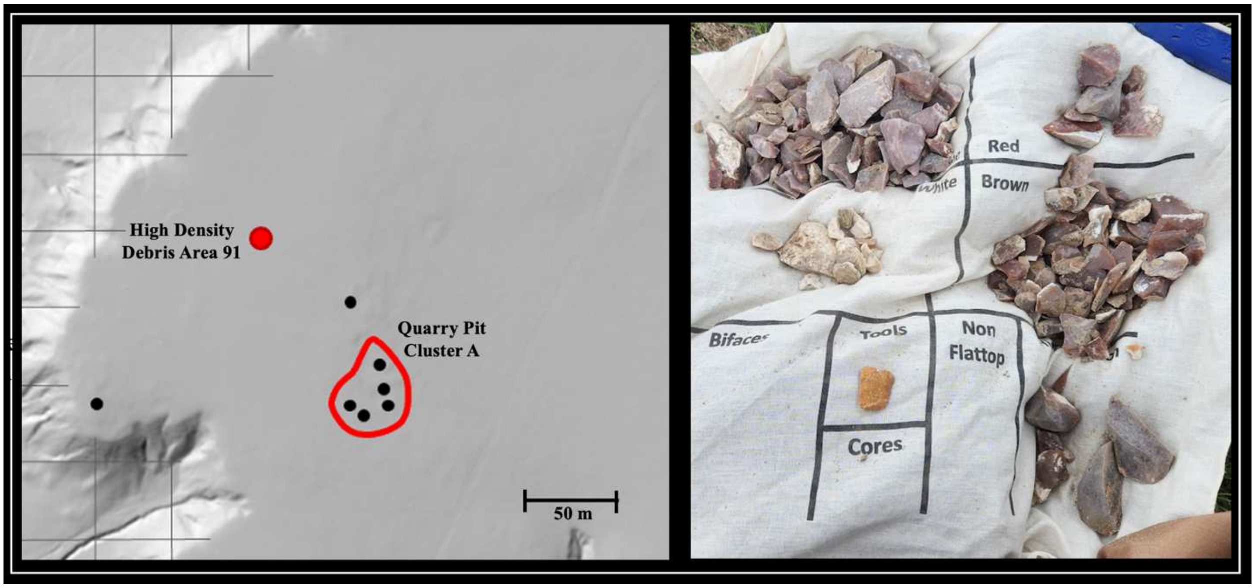

Figure 56. High-density debris unit 91.

As discussed in Chapter Six, these high-density debris areas are interpreted as possible secondary reduction workshops, such as those frequently observed at other quarry sites in North American (Ahler 1986:107; Fritz 2021; Gardner 1977; Metcalf et al. 1991:98), where masses of tool-stone that had previously been extracted from quarry pits, and initially tested and reduced there, were transported to these more distant locations for further reduction into transportable, high-value packets of raw material.

The appearance of an Agate Basin projectile point in the middle of a possible secondary reduction workshop suggests the possibility that the reduction episode(s) that occurred in this location dates to 12,500-11,500 calibrated years before the present.[26] Further support for this possible early date comes from the patination specimens collected from this same high-density debris areas, which contained the highest number of heavily patinated specimens recovered on the butte (Appendix G).

Archaic Period Locations

Two locations on Flattop Butte are associate with the Archaic period. The first is high-density debris area in survey Unit 132, located in the north-Central portion of butte, where a temporally diagnostic Duncan-Hanna dart point was found surrounded by around 200 cm^3 (.5 kg) of chalcedony flakes and chunks (Figure 57). The appearance of a Duncan-Hanna point at this location suggests the possibility that this high-density debris area could represent the remains of a chalcedony secondary reduction workshop dating to between 5700 and 2250 calibrated years before the present.[27]

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[26] The proposed association of the lithic reduction debris observed in this high-density debris with the Agate Basin projectile point is premised on the assumption that the projectile point was discarded by the same individuals who produced the reduction debris, and that all of these materials have remained on the surface of the butte, undisturbed, for the last 12,000 years. Other explanations are possible.

[27] The proposed association of the Duncan-Hanna dart point with this lithic reduction episode rests on the untested assumption that the projectile point was discarded by the same individuals who produced the reduction debris observed, and that all of these materials have remained on the surface of the butte, undisturbed, since that time.

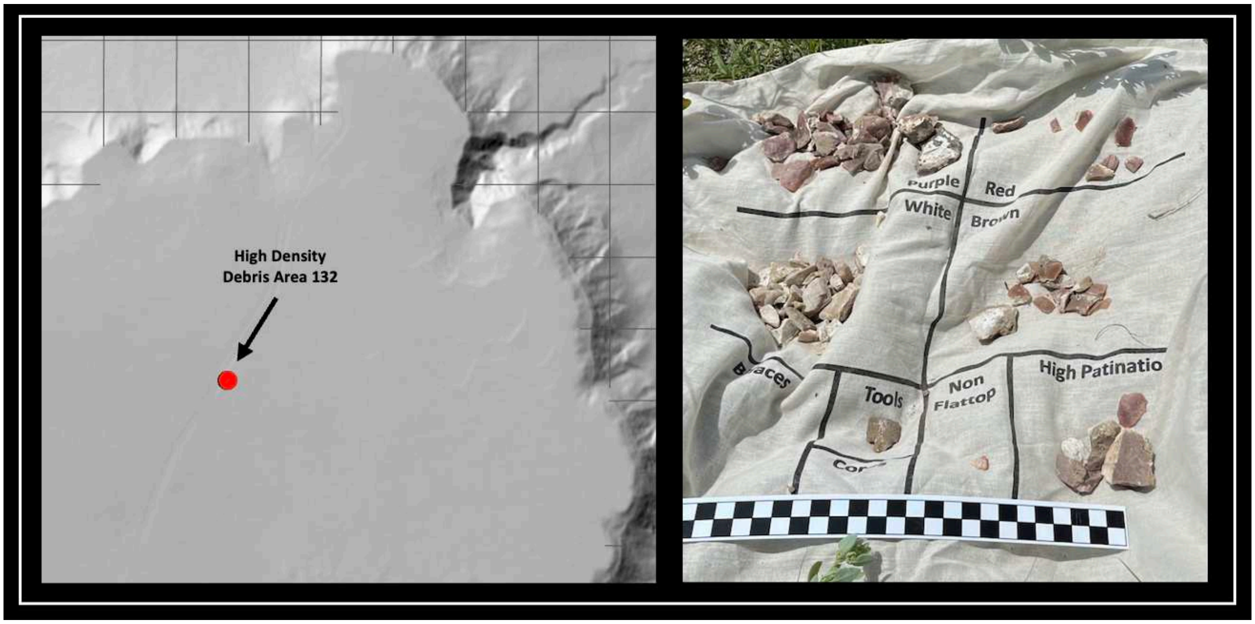

Figure 57. High-density debris area in survey Unit 132.

The second location associated with an Archaic period date is a buried thermal feature (hearth), found eroding from the western edge of an erosional wash at the south-Central portion of the of the butte (Figure 58). Organic residue on a sample of burned rock from this feature returned a calibrated date of around 2700-2600 years before the present (Appendix F).

Figure 58. Location of Late Archaic period thermal feature.

Evidence is sparse as to the activities that were associated with this thermal feature. Hearths have been found to be associated with both habitations and secondary reduction workshops at quarries in the region (Ahler and Christensen 1983:281; Metcalf et al. 1991:96). Here, the available evidence suggests the possibility of a workshop, although this is far from clear. The hearth is partially buried under 21 cm of topsoil and exposed only in the edge of the erosional wash, making it impossible to determine whether it is part of or near to a high-density debris area. However, the hearth is associated with two pieces of Flattop chalcedony debris, visible at the bottom right of Figure 59, a large flake (2.5 cm in length) and an irregular chunk (6 cm in length). Both of these pieces of reduction debris are of the size and character of debris typically found in high-density debris zones/workshops, as opposed to the smaller flakes produced by tool finishing and maintenance typically found at quarry habitation locations (Ahler and Christensen 1983:Table 1; Metcalf et al. 1991:95).

In addition, as shown in Figure 59, the hearth at issue here is located between two quarry pit clusters, one approximately 150 m to southwest and the other 90 m to the southeast. It is also located in an area of medium to medium-high debris density. Thus, this hearth is located within what could be termed a production zone where secondary reduction workshops are common, as opposed to habitations which are typically located at a greater distance from production areas at quarry sites (Ahler and Christensen 1983:Table 1; Fritz 2021; Gardner 1977; Metcalf et al. 1991:95).

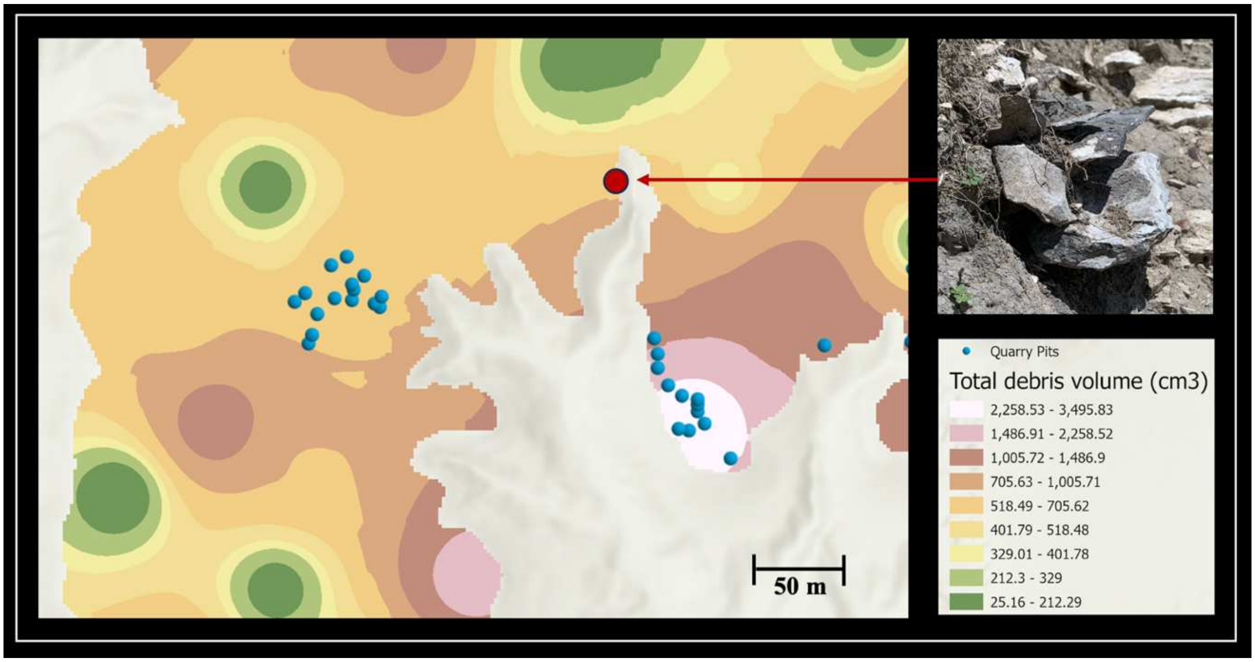

Figure 59. Location of quarry pits and debris volumes in the area of Late Archaic period thermal feature.

Late Prehistoric Period Locations

Two locations on Flattop Butte are associated with the Late Prehistoric period. The first is a quarry pit in the northeastern portion of the butte, in which the excavation project described above took place. The second is an area in the southwestern portion of the butte where stone circles were reported by previous visitors to the site. Each of these is discussed in turn below.

As previously discussed, significant amounts of dateable materials, all dating to the Late Prehistoric period, were recovered from the excavation unit located in quarry pit Cluster B. Specifically, nine radiocarbon dates were obtained from bone recovered at a variety of depths (Figure 60). These dates range from around 1066 to 553 median, calibrated years before the present, with five of the dates clustering between 649 and 695 calibrated years before the present, and two others falling between 794 and 795 calibrated years before the present. In addition, a diagnostic arrow point, associated with Upper Republican groups operating in the vicinity of

Flattop Butte around 1000 to 700 calibrated years before the present (Scheiber and Rehr 2007), was recovered at a depth of between 55 and 94 cm in the excavation unit (Figure 60). These dates suggest at least two distinct Late Prehistoric period quarrying episodes at this location, in addition to several other less well-defined events.

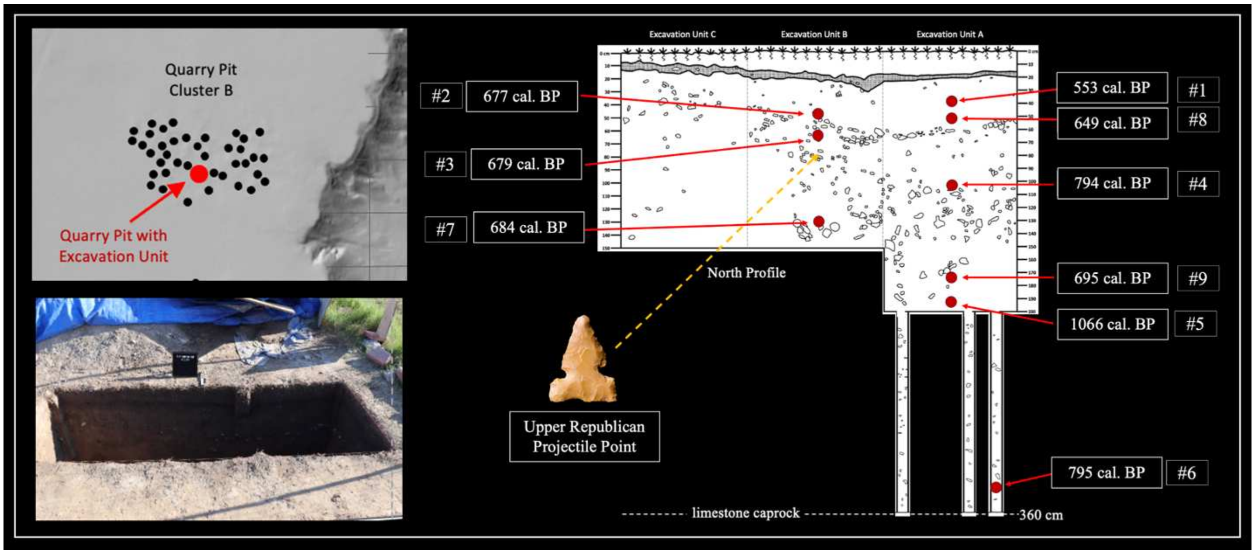

Figure 60. Location and dates recovered from excavation unit.

The first such episode is associated with three bison bone fragments recovered between 55 and 67 cm of depth with median dates of 677, 679, and 649 calibrated years before the present (Figure 60). All of these dates are within the margin of each other, suggesting that they are associated with the same event. Moreover, as previously discussed, one of these bone fragments was located on top of a compacted "lens" of reduction debris, and the other was located embedded in this lens, which is visible in the north profile of excavation unit B between 55 and 94 cm of depth (Figure 60). In addition, the two halves of a broken biface were recovered on top of and underneath this debris lens (Figure 42), and the remaining bone fragment (sample 8) was recovered just to the east in excavation unit A, slightly above what appears to be the same debris lens continuing from unit B into unit A (Figure 60).

This evidence suggests the possibility that the debris lens observed here was formed in a single reduction episode, or a series of related episodes, as chalcedony was initially reduced in or near the quarry pit location, and the resulting debris was backfilled into exhausted portions of the excavated area as the pit moved laterally to uncover additional lithic materials. As illustrated in Figure 61, similar patterns of reduction debris mixed with overburden, and backfilled into and over exhausted areas of quarry pits are frequently observed in quarry locations in North American (Ahler 1986:32-37; Frison and Stanford 1982:174; Fritz 2021).

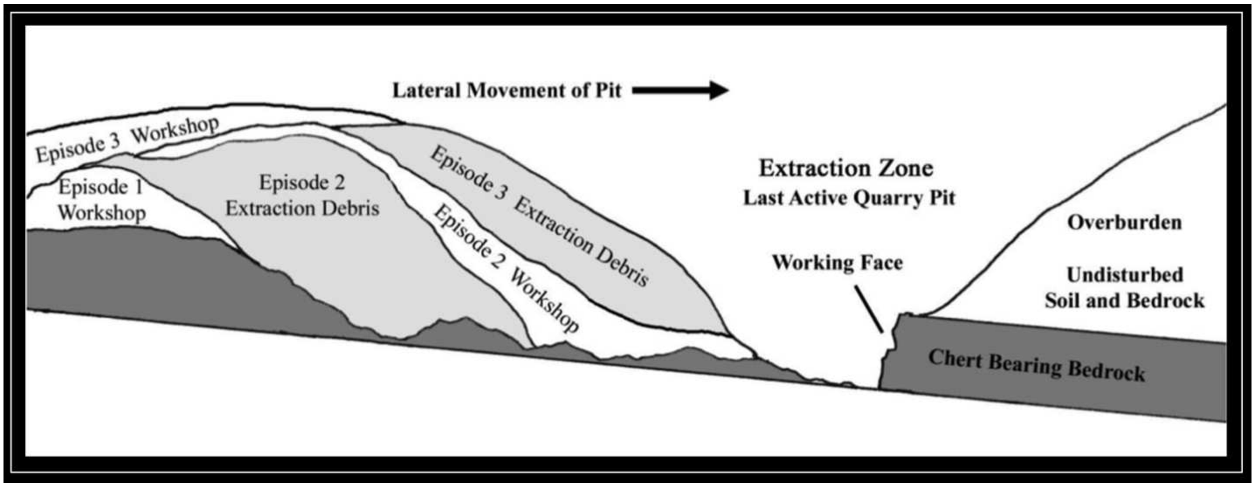

Figure 61. Illustration of backfill process in an idealized quarry pit. From Fritz (2021: Figure 7).

Two additional bison bone fragments are also possibly associated with this same Late Prehistoric period quarrying event. The first of these was recovered in excavation unit B at a depth of 132 cm, and is dated to around 684 calibrated years before the present, well within the margin of error for the two dated bison bones samples above it in unit B associated with the debris lens (Figure 60). The second bone fragment possibly associated with this same quarrying event was recovered in excavation unit A between 170 cm and 180 cm of depth, and was dated to around 695 calibrated years before the present (Figure 60). Again, this date is within the margin of error for the other bone samples associated with the quarrying event that produced the debris lens. While these two bone fragments were found significantly deeper than the two similarly dated fragments associated directly with the debris lens, it is possible that a single quarrying event produced all of the fill associated with these dated bone fragments, and they became mixed in the overall backfilling process that resulted in them being redeposited in exhausted areas of the quarry pit.

However, linking these deeper fragments to the debris lens event is complicated by the fact that another bone fragment, dated to around 794 calibrated years before the present, around 100 years before the debris lens was produced, appears in excavation unit A between the lens and the deeper, similarly dated bone fragments (Figure 60). The interposition of this earlier dated bone fragment may have resulted from repeated quarrying episodes over long periods in the same general location where overburden and quarrying debris were mixed and backfilled in exhausted quarry pits (Ahler 1986:32-37; Frison and Stanford 1982:174; Fritz 2021). For example, at the Knife River flint quarry, excavations by Root revealed that quarrying episodes over thousands of years in the same locations often “churned through earlier deposits mixing artifacts of different ages and obscuring the details of earlier quarrying episodes” (1992:262).

Separate and apart from the debris lens producing episode, a possible second, distinct Late Prehistoric quarrying episode may be associated with five bone fragments from what is likely the same grey wolf, recovered between 40 cm and 44 cm of depth in excavation Unit A, dated to around 577 calibrated years before the present (Figure 60). Reduction debris encountered at these levels is significant, although not as substantial as the debris lens discussed above (Figure 40; Appendix H). The fact that these wolf bones were deposited above this debris lens, and predate it by roughly 100 years, suggest that they, together with the reduction debris associated with them, represent a later quarrying episode in which materials were backfilled over the previously deposited debris lens.[28]

In addition to the excavated quarry pit, the second location on Flattop Butte associated with the Late Prehistoric period is the far southwest portion of the butte where stone circles were observed by past visitors to the site (Jensen 1973; Renaud 1930; Wilbur's 1981).). Stone circle sites are typically associated with habitations (Davis 1983; Long 2011; Meeker 2017). In northeastern Colorado they have been dated to between 2000 and 150 calibrated years before the present (Long 2011; Morris et al. 1983), indicating a Late Prehistoric period date for these possible features at Flattop Butte.

Overview

As the forgoing discussion details, the survey and excavation work conducted here identified four locations with associated dates on Flattop Butte (Figure 54): (i) a possible Paleoindian period secondary reduction workshop dating to around 12,500 to 11,500 calibrated years ago, (ii) a possible Archaic period secondary reduction workshop dating to between 6800 and 2800 calibrated years before present (most likely from and after 3500 calibrated years before present), (iii) an Archaic period location, possibly a secondary reduction workshop, dating to between 2700 and 2600 calibrated years before the present, and (iv) a quarry pit dating to between 1066 and 553 calibrated years before the present. Finally, reports of stone circles in the far southwest portion of the butte indicate the presence of Late Prehistoric period habitations in this area.

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[28] Statistical analysis of the radiocarbon dates obtained here would likely produce additional information regarding the sequence of activities that produced the mix of dated materials recovered in the quarry pit excavation.

CHAPTER 6 – SPATIAL ORGANIZATION

The next research question presented here is concerned with spatial organization at Flattop Butte, and asks: did prehistoric peoples organize their production at the site in separate, specialized activity areas, and if so, where on the site were these located? Investigators working at quarry sites in the region have categorized different types of activity areas using the classification system created by Binford (1980) for distinguishing between the activities of forager and collector groups based on assemblage characteristics (Ahler 1986:107-108); Metcalf et al. 1991:95-98; Nowak and Hannus 1985:103, 106). In this classification system, hunter-gatherer subsistence/settlement strategies are divided into two types: (i) the forager strategy, in which groups "map onto" resources through frequent residential moves, and (ii) the collector strategy, in which groups occupy longer term residential bases, and supply themselves by deploying specially organized task groups to obtain and retrieve resources from remote locations (1980:10).

The first of these activity area types found at quarry sites are quarry pits or outcrop locations. These are categorized under Binford's (1980) typology as "locations," defined as a places "where extractive tasks are exclusively carried out" (1980:9). The second activity location type typically found at quarry sites are secondary reduction workshops, which are also categorized under Binford's typology as "locations" (1980:9). The final activity location type typically found at quarry sites are habitations, which are categorized under Binford's typology as "field camps," defined as temporary operational centers used by task groups to eat, sleep, and otherwise maintain themselves at resource locations while they are away from their primary residential base (1980:10). Evidence for the existence of quarry pits, secondary reduction workshops, and habitations at Flattop Butte, and the types of tasks carried out at that these activity areas, is discussed in more detail below, followed by a discussion of their locations and spatial relationships.

Quarry Pits

Quarry pits are the most easily identified activity area on the surface of Flattop Butte. As previously discussed, many quarry pits are clearly discernable from the appearance of large surface depressions, often accompanied by what appear to be the remains of adjacent spoil piles (Figure 18). In other cases, quarry pits are identifiable from the presence of isolated, circular to oval outcrops of western wheatgrass (Figure 19).

Activity Types

The evidence gathered here demonstrates two main types of activities occurring at quarry pit locations on Flattop Butte: extraction, and initial reduction, of Flattop chalcedony. In addition, evidence of possible subsistence activities in support of quarry workers was also recovered in quarry pit excavated here. The evidence for each of these activity types is discussed below.

Extraction

The most obvious evidence of lithic extraction activities at the quarry pit locations are the pits themselves. These surface depressions and/or western wheatgrass concentrations, are the visible remnants of ancient groups: (i) digging into the surface of Flattop Butte, (ii) removing top soil overburden until the buried limestone caprock was reached, (iii) breaking through the caprock and exposing the chalcedony encased within, (iv) removing this material for further processing, and (v) backfilling the pit with overburden and reduction debris as the bottom of the pit moves laterally to expose additional lithic materials (Figure 62). Both the CMPA quarry pit excavation carried out here, and the Greiser 1976 quarry pit test trench, offer ample evidence of this process. Both excavations encountered disturbed fill consisting of soil intermixed with large volumes of chalcedony debris, as well as large slabs of limestone with fragments of Flattop chalcedony still attached, broken away from the buried caprock (Figure 40) (Greiser 1983).

In addition, some of the bone fragments recovered in the CMPA excavation unit are likely broken pieces of digging tools. Investigations at other quarry sites in the region have identified bison ribs, long bones, dorsal spines, and scapula as among the types of bones used by ancient people as digging tools at these locations (Ahler 1986:76; Ahler and Christensen 1983: 205; Metcalf et al. 1991:44). Here, 165 bone fragments were recovered in the quarry pit excavation unit, including many that are identifiable as bone types typically used as digging tools, including two bison rib fragments, a bison long bone (femur) fragment, and six fragments of grey wolf long bones (three radius, two humerus, and one ulna) (Appendix I).

Initial Reduction

The large volumes of Flattop chalcedony flakes and chunks encountered in quarry pit fill in both the CMPA and Greiser locations also demonstrate that initial reduction activities were occurring at the quarry pit locations. Likewise, the heavy chalcedony debris concentrations encountered at a variety of depths in the excavation carried out here provide further evidence of initial reduction activities occurring at this quarry pit location. In addition, the small hammerstones recovered in the excavation unit, more suitable for chipping chalcedony than for breaking through thick limestone, suggest initial reduction occurring at the quarry pit location, as do two rejected cores and two rejected bifaces, recovered in the quarry pit fill (Figure 42 and 43).

Subsistence

In addition to evidence of lithic extraction and reduction activities, the quarry pit excavation produced other evidence that may indicate possible subsistence activities being carried out at this location. For example, fragments of bison bones not normally associated with use as digging tools (mandible, phalanx, pelvis, and eye socket) were recovered in the excavation unit (Fig 46) (Appendix I). In addition, 27 burned bone fragments, 36 pieces of charcoal, and 6 pieces of burned wood were recovered at various depths in the excavation unit (Appendix I and K). These materials suggest the possibility of one or more hearths being present in the quarry pit area and the possible cooking of meat for the provisioning of quarry workers, with trash from these activities being disposed of in the quarry pit backfill.

Locations and Spatial Relationships

A total of 128 quarry pits were identified and mapped on the surface of the Flattop Butte, with 124 of these pits concentrated in seven distinct clusters in the Central portion of the butte (Figure 63). No quarry pits were located in either the northern or southern portions of the butte. The central portion of the butte, where Flattop chalcedony was extracted, is identified here as the lithic extraction zone (Figure 62).

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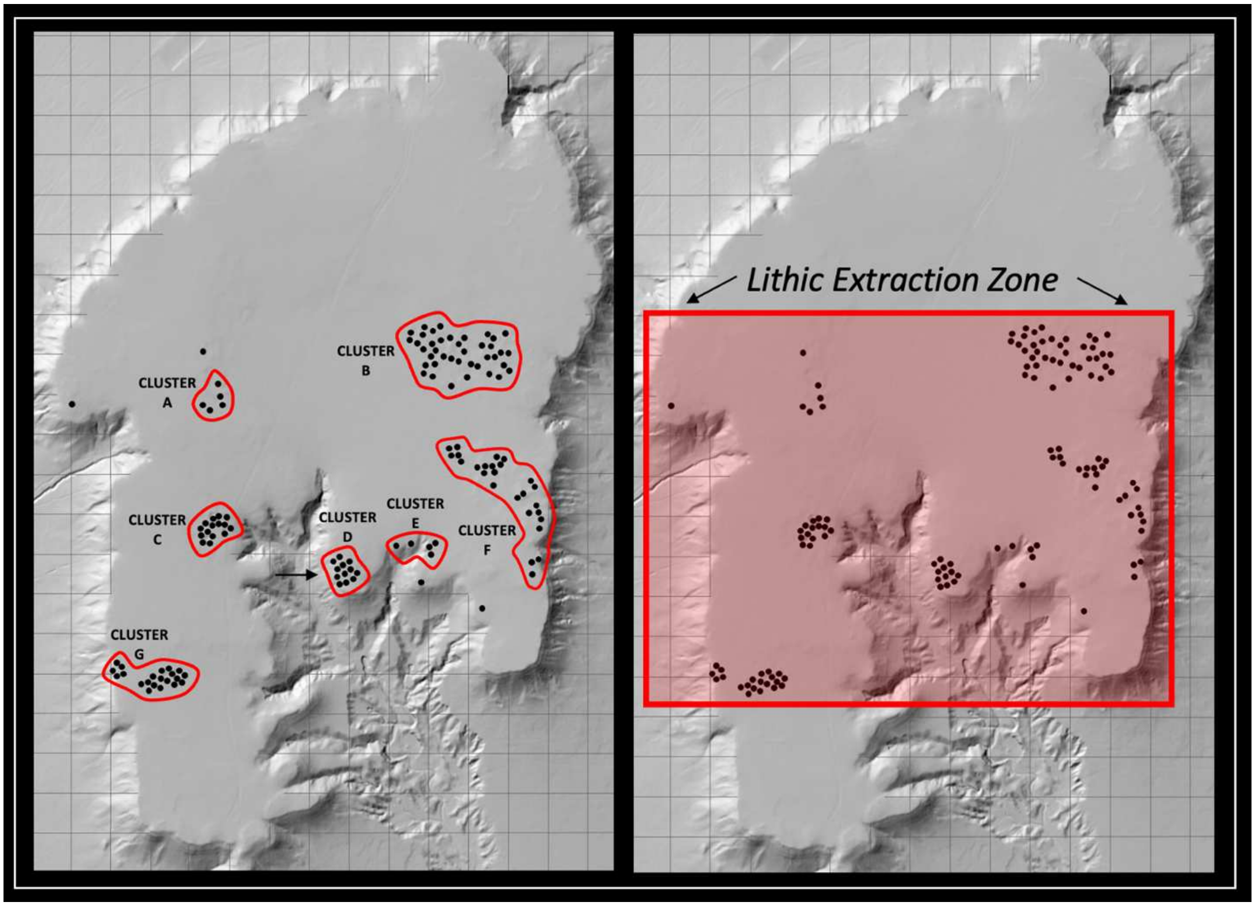

Figure 62. Location of quarry pits, quarry pit clusters, and lithic extraction zone.

The spatial parameters of this lithic extraction zone, and the specific locations of quarry pits and pit clusters contained within it, were most likely conditioned by three factors: (i) the presence of substantial deposits of sub-surface, high-quality lithic materials, (ii) the depth at which these materials were deposited beneath the surface, and (iii) the skill and ability of ancient groups to locate the most easily accessible deposits. Each of these factors is discussed below.

First, it appears unlikely that high-quality deposits of chalcedony are present beneath the surface of Flattop Butte at all locations. The fact that quarry pits are limited to the central lithic extraction zone suggests this limitation. Moreover, if high quality material was uniformly distributed, it seems unlikely that quarry pit clusters would be as limited in size and separated by as significant distances as are observed, in that there would seem to be little reason why ancient groups would abandon a productive quarrying location to start again at a new distant location unless the abandoned location was exhausted. These facts suggest that high-quality Flattop chalcedony appears in limited, spatially confined and separated deposits, occurring only in the lithic extraction zone described above, which would necessarily constrain the location of quarry pit locations on the butte.

The second factor conditioning the location of quarry pits and clusters at Flattop Butte is the depth at which chalcedony deposits are bedded at different locations across the butte. As discussed in Chapter Three, the Greiser quarry pit test trench in cluster C and the CMPA quarry pit excavation in cluster B found that the depths of the chalcedony-bearing limestone caprock at these two locations are dramatically different: approximately 90 cm at the Greiser location versus 360 cm at the CMPA location. Because chalcedony deposits are present at significantly different depths at different locations, the costs of extraction, in time and labor required, at different locations would also vary significantly (Table 3). As a result, ancient groups would have been highly motivated to seek out and exhaust deposits of high-quality material appearing closest to the surface before moving on to more deeply buried deposits.

The final factor conditioning the location of quarry pits and clusters at Flattop Butte is the skill and ability of ancient groups to locate the most easily accessible buried deposits of high-quality chalcedony. This is so because, as just noted, when digging for buried lithic materials, the greater the depth, the greater the cost. Thus, it would be highly advantageous for ancient groups working at Flattop Butte to exploit chalcedony deposits at the lowest possible depths, to the extent that they had the skill and ability to locate these deposits.

There is reason to believe that these groups may have had these skills and abilities. Humans and their ancestors have been searching for and acquiring tool stone since well before the emergence of *Homo sapiens* (Agam 2020). This suggest that "over hundreds of thousands of years of cultural evolution, people had become good 'geologists'" (Purdy 1984:119). Moreover, the costs of prospecting for shallowly buried deposits of high-quality chalcedony at Flattop Butte would not have been high, particularly when compared to the wasted costs of digging for lithics at significant depths when shallower deposits were available. The digging of tests pits would quickly reveal if shallowly buried chalcedony deposits of sufficient quality were present at a given location, and when these were located, they could be exploited until the deposit was exhausted. This suggests the possibility that there may be a correlation between the locations of quarry pits and quarry pit clusters and locations of the least deeply buried, not already exhausted, deposits of Flattop chalcedony at the butte.

Another possible correlation is also suggested between the depth of deposits at quarry pit locations and their age, given that ancient groups would have had the incentive and possibly the ability to locate, exploit, and exhaust the most easily accessible deposits of chalcedony at the butte before moving on to more deeply buried deposits. This suggests the possibility of an inverse relationship between the depth of chalcedony deposits at the various quarry pit cluster locations and the period during which these locations were exploited, such that quarry pits clusters over shallow deposits could be expected to be older than those over more deeply buried deposits. Following this logic, it is possible that quarry pit cluster C, where the Greiser test trench revealed deposits at approximately 90 cm of depth, is older than quarry pit cluster B, where the CMPA excavation revealed deposits at 360 cm of depth.[29] However, it should be acknowledged that the

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[29] A number of variables not considered here could invalidate this inference with respect to any particular quarry pit or quarry pit cluster. For example, average projectile point size generally decreased in the Great Plains from the Paleolithic period, through the Archaic period, and into the Late Prehistoric period, meaning earlier groups would tend to require quarry locations that could produce larger packets of useable lithic raw materials than later groups. Similarly, Paleoindian

current data set is limited to two of 128 quarry pits (only one of which is dated) in two of seven quarry pit clusters, meaning significant additional data would be needed to confirm or disprove the correlation suggested here.

Secondary Reduction Workshops

As previously discussed, investigations at other quarry sites in North America have consistently identified lithic reduction activity areas, characterized by large volumes of dense reduction debris, located at a distance from quarry locations, as workshops where secondary reduction of quarried material took place (Ahler 1986:107; Ahler and Christensen 1983:21; Gardener 1977; Fritz 2021; Metcalf et al. 1991:96). The activities at these secondary locations are described as the further reduction of already reduced materials into forms more suitable for transportation and use away from the site. These are said to be distinct from initial reduction workshops that are located at or in the immediate vicinity of an extraction location, which produce reduction debris and assemblages reflecting their earlier stage in the production process (Ahler 1986:107; Fritz 2021; Metcalf et al. 1991:98).

A number of similar locations were observed at Flattop Butte. As previously discussed, it was observed that quarrying debris on the surface of the butte tends to be concentrated in isolated, fairly well defined, often roughly circle-shaped, high-density debris areas with an average size of around 1 m^2 (Figure 16). In surveying the surface of the butte surveyors were therefore instructed

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period groups tended to produce projectile points evidencing a higher degree of craftsmanship as compared to later groups, which required lithic raw materials of very high quality to produce (Hayden 1982), meaning these Paleoindian groups would tend to require quarry locations that could produce such high-quality materials. These or any other variables that would tend to cause differences in the characteristics of lithics required by different groups would therefore skew the inverse relationship suggested here between depth of lithic deposits and the age of quarrying activity.

to locate, photograph, and map a 1 m^2 sub-unit in each 60 x 60 m survey unit, placed at the center of the highest volume, high-density debris area in each survey unit, and to measure the total volume of chalcedony debris found in each such 1 m^2 sub-unit. These 78 high-density debris subunits were then ranked by volume, divided into quintiles, and assigned ordinal designations of very-high (3500-1100 cm^3), high (1050-650 cm^3), medium (600-300 cm^3), low (299-50 cm^3) and very-low (less than 50 cm^3) debris density (Appendix K).

Clearly, not all of these debris areas are candidates for secondary reduction workshops. The volume of many are small and contain only scatters of debris. Others are large enough, but they are close to quarry pits, which would make them more consistent with initial reduction workshops (Ahler 1986:107; Fritz 2021; Metcalf et al. 1991:98).

However, thirty-five of the mapped and measured high-density debris areas are more than 25 meters from nearest quarry pit, and contain not less than 300 cm^3 (and as much as 3600 cm^3) of chalcedony debris concentrated in an isolated, 1 m^2 area. Based on these characteristics, these 35 locations are identified, and discussed in more detail below, as possible secondary reduction workshops.[30] Further lithic analysis of the reduction stage of the contents of these location (not conducted here) would be necessary to confirm this identification.

It should also be recognized that these 35 locations do not represent the only possible secondary reduction workshops on the surface of the butte. Only around half of the 60 x 60 m units covering the surface of the butte were selected for survey (using a checkerboard pattern) meaning that possible workshops in the non-surveyed units were not recorded. In addition, surveyors

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[30] The criteria used here to identify possible secondary reduction workshops – at least 300 cm^3 of lithic debris in an isolated 1 m^2 area, located more than 25 m from the nearest quarry pit – while somewhat arbitrary, are intended to capture locations that match the patterns observed for secondary reduction workshops at other quarry locations in North America.

encountered many high-density debris areas is their survey units, but recorded only the highest density area in each unit. Thus, other high density debris areas in these units were not considered, many of which would qualify as possible secondary reduction workshops under the criteria employed here.

Activity Types

The activities that can be identified as occurring at the 35 secondary reduction workshops identified here are limited. The large volumes of flakes and irregular chunks of chalcedony that appear in them make clear that large masses of chalcedony removed from quarry pits were transported to them, subjected to further reduction, and then removed. No detailed lithic analysis of the debris contained in these workshops was performed here, meaning that no additional detail can be provided regarding the reduction techniques employed or the ultimate forms (such as bifaces and or cores) that these reduction efforts were directed towards.

Locations and Spatial Relationships

The locations and relative volumes of debris at the areas identified here as secondary reduction workshops, together with their spatial relationships with quarry pit locations, are illustrated in the left panel of Figure 63. There, the relative debris volume recorded for each workshop is depicted by a circle centered on each location, colored red for very-high debris volume, brown for high, and yellow for medium, with the size of the colored circle representing the relative debris volume present as compared to the other locations.

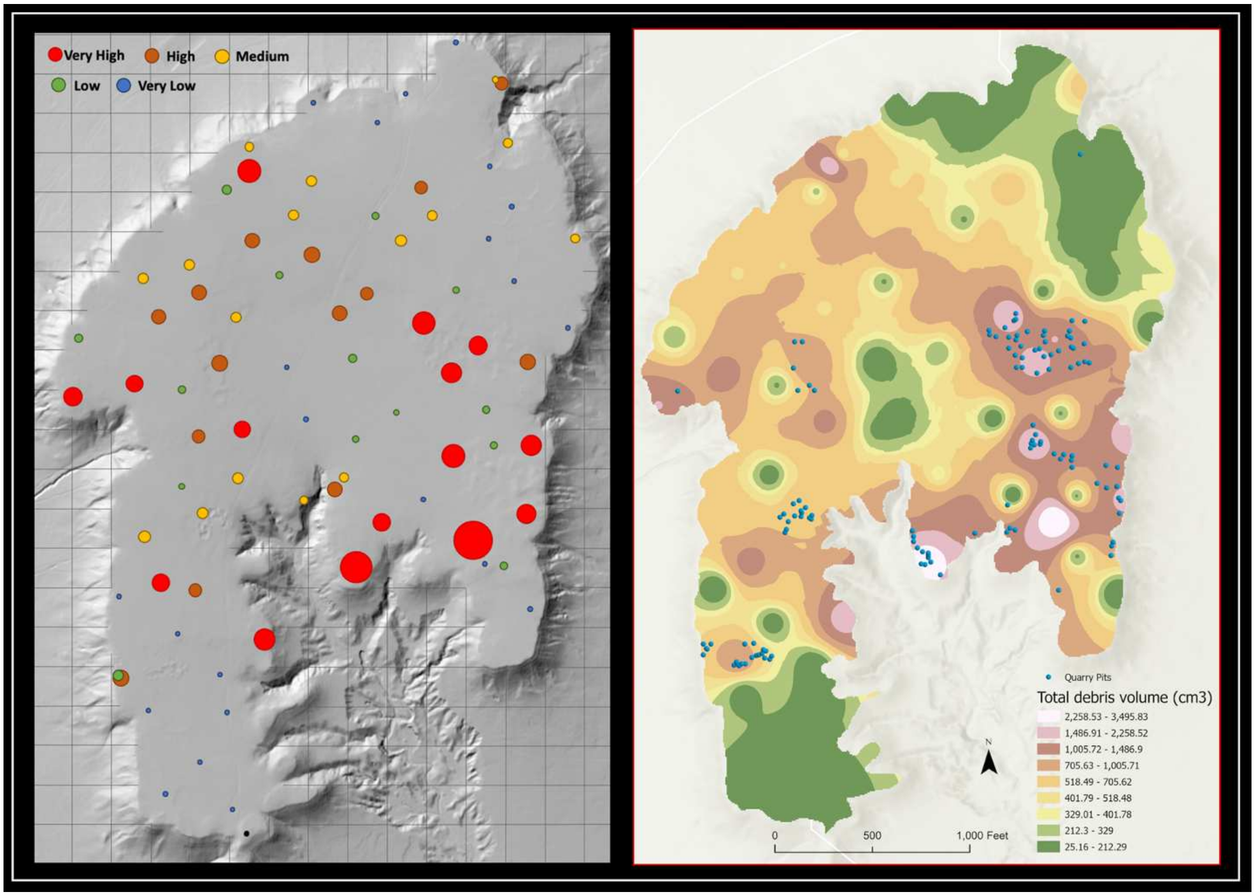

Figure 63. Maps of secondary reduction workshop and quarry pit locations (left), and extrapolations of debris volumes based on inverse distance weighting* (right). *Created by Joshua Reyling, Geospatial Centroid, Colorado State University.

The area enclosing 33 of the 35 secondary reduction workshop locations is illustrated in Figure 64 by the blue-shaded area covering the central portion of the butte, referred to here as the lithic reduction zone.[31] The extent of this lithic reduction zone is also visible in the debris volume map in the right panel of Figure 63 which was produced using inverse distance weighting to extrapolate the volume between measured high-density debris areas based on the average volume of nearby measured areas.

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[31] Three secondary reduction workshops were identified outside this lithic reduction zone and are located at the northeastern edge of the butte, two in close proximity to each other and the third at a distance (Figure 64).

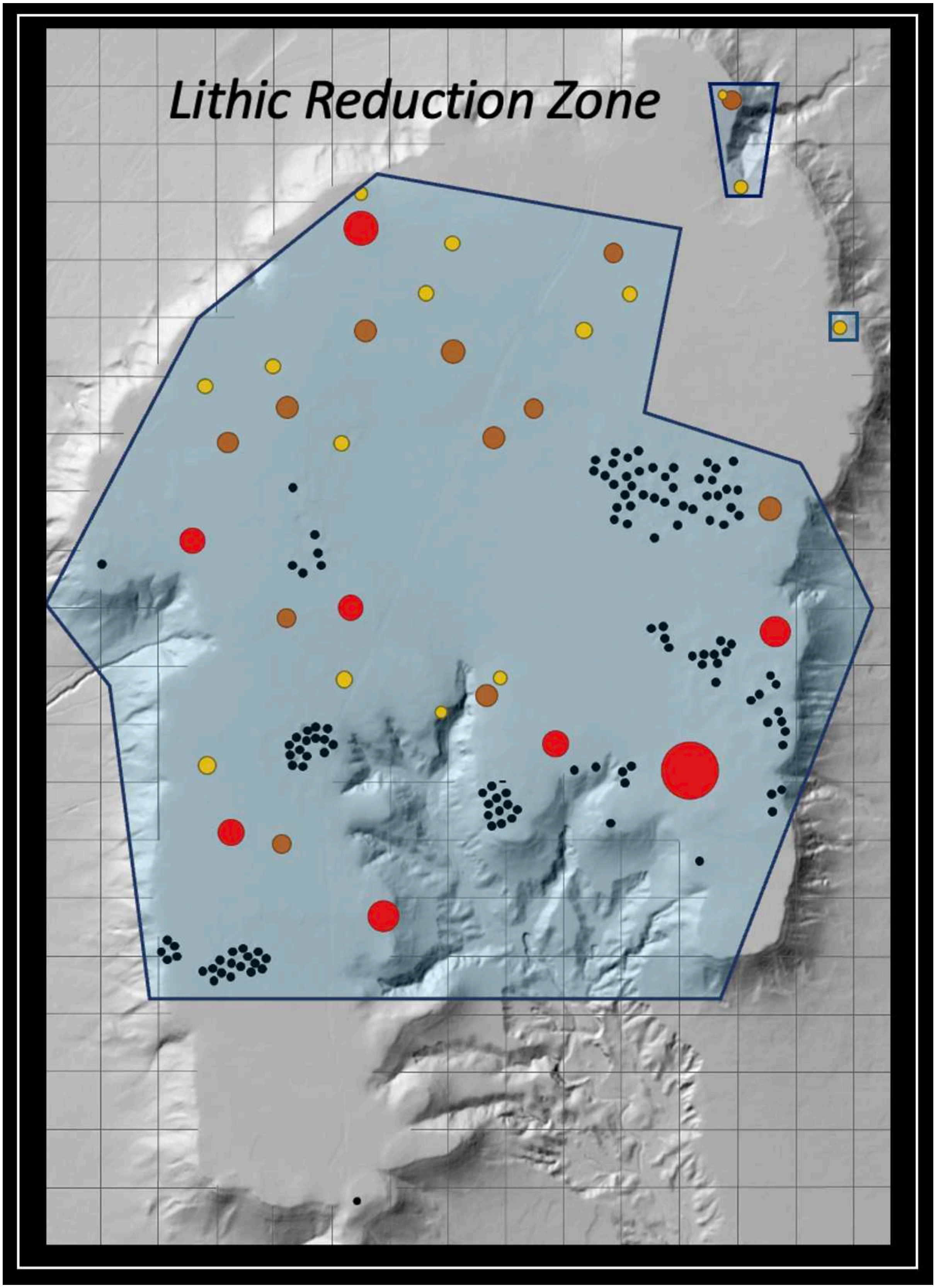

Figure 64. Lithic extraction zone.

Like the lithic extraction zone, defined by the spatial extent of the quarry pit locations, the lithic reduction zone defined here is confined to the central portion of Flattop Butte and (with limited exceptions) does not extend into the farthest northern and southern portions of the butte (Figure 65). However, the lithic reduction zone extends farther into the northern portion of the butte than the lithic extraction zone (Figure 65). Indeed, in two seemingly isolated locations, secondary reduction workshops appear near the northern tip of the butte, far removed from any quarry pit location identified here (Figure 65).

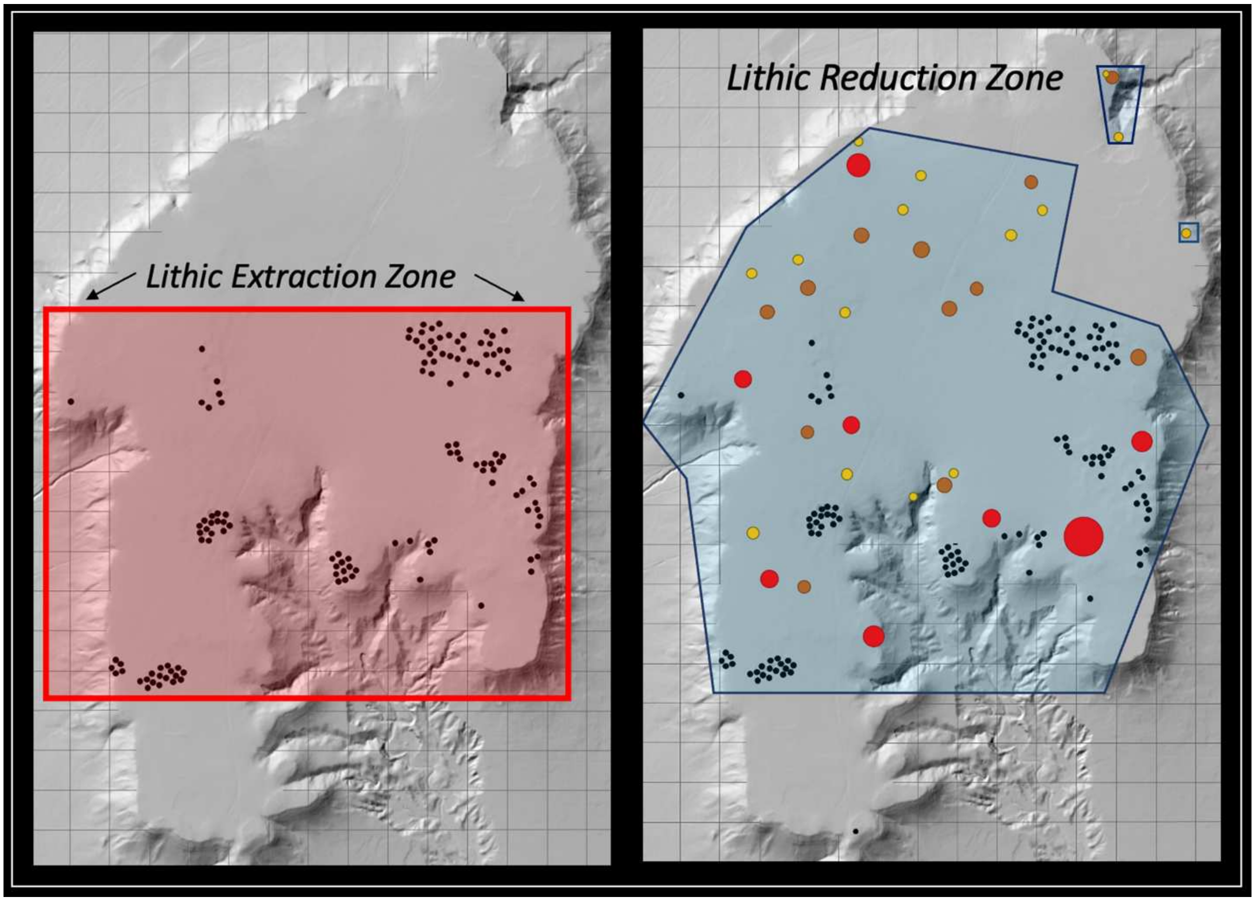

Figure 65. Comparison of lithic extraction zone and lithic reduction zone.

This is not altogether surprising given the pattern recognized at other ancient quarry locations in the region in which secondary reduction workshops are located at a distance from quarry pits, where extraction and initial reduction of raw materials occur (Ahler 1986:Figure7;

Fritz 2021; Metcalf et al. 1991:Figure5.2). However, in some of these cases the distances are unusually significant, as for example in the case of the very-high volume possible workshop located at the northernmost point of the lithic reduction zone, which is around 350 m distant from the nearest quarry pit cluster (Figure 65). It is unclear why ancient groups would transport large masses of chalcedony this far from a quarry pit for further reduction, raising the possibility that there are other, undetected quarry pits in the northwest portion of the butte that were missed in the survey.

The area encompassed by the lithic reduction zone, and the locations of end scrapers and side scrapers recovered on the surface of the Flattop Butte, suggest another possibility for an activity type carried out in or around the possible secondary reduction workshops identified here. Of the 14 side scraper and 12 end scrapers recovered, 24 were located in the lithic reduction zone (Figure 66), with five of these being located directly in possible workshop locations (Appendix D). Scrapers are typically associated with hide working (Hayden 1979; Scheiber and Reher 2007). The fact that a significant number of scrapers were located on the surface of the butte, and over 90% of these were recovered in the lithic reduction zone, suggest not only that hide working was occurring at the butte, but also that it was occurring in and around the possible secondary reduction workshops identified here.[32]

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[32] Of the 26 scrapers recovered on the butte, only three were made of exotic (non-Flattop chalcedony) materials, originating from other lithic source locations (Appendix E). This suggest the possibility that most (if not all) of the scrapers recovered on the butte surface were present there because they had been used on-site for hide working, as opposed to being spent tools that were simply discarded at the site in favor of new tools produced there as part of a “gearing up” process. It is also possible that these Flattop chalcedony scrapers were made and used off-site from materials acquired in previous quarrying episodes, and were later discarded at the site in a similar gearing-up process.

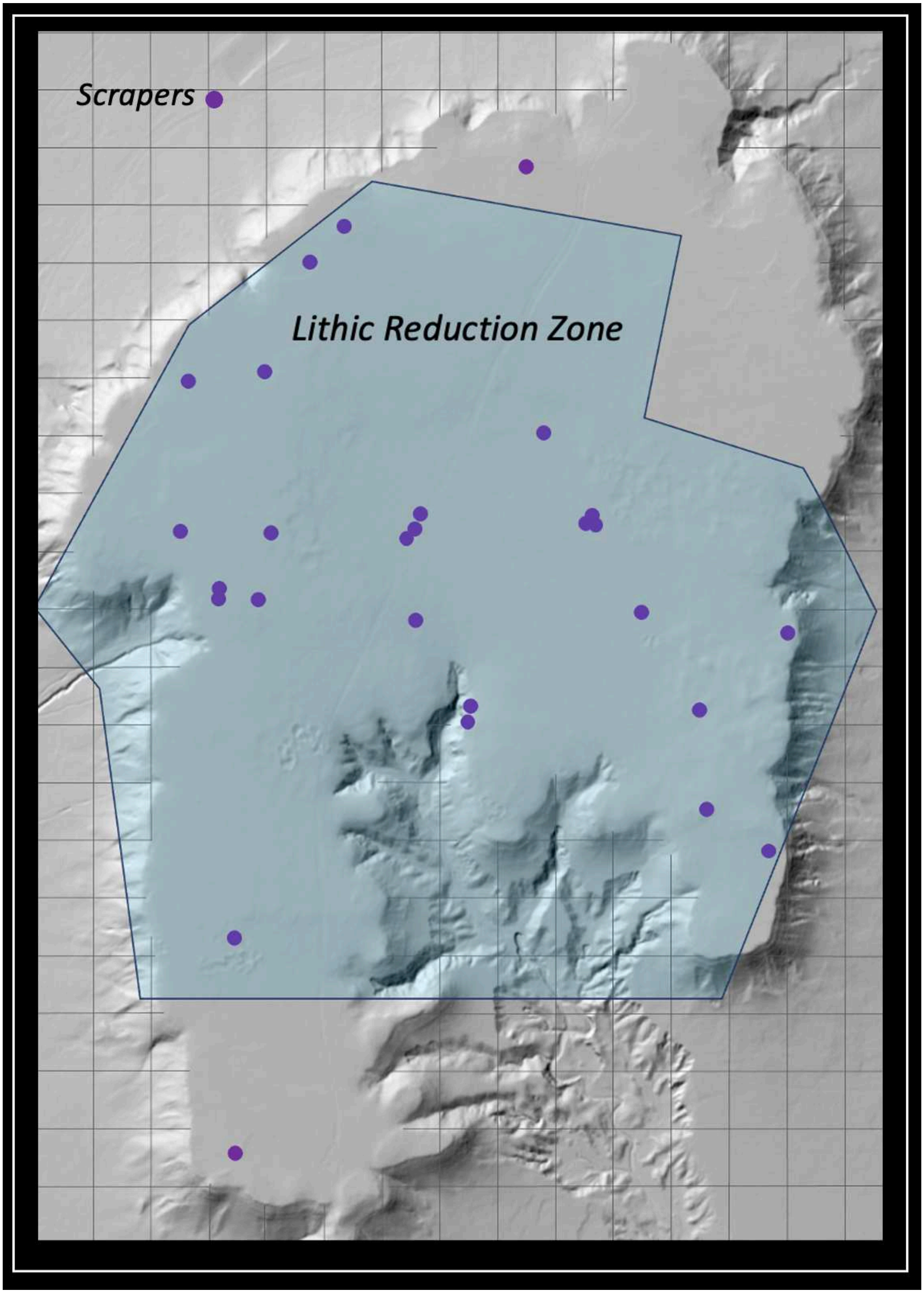

Figure 66. Comparison of scraper locations and lithic reduction zone.

Habitations

Habitations, or what Binford termed "field camps," i.e., temporary operational centers used by task groups to eat, sleep, and otherwise maintain themselves at resource locations while they are away from their primary residential base (1980:10), are frequently found at quarry locations, often set off at a distance from quarry pits and secondary reduction workshops (Ahler 1986:107-108; Fritz 2021; Gardner 1977; Metcalf et al. 1991:94-98). Evidence for habitations on Flattop Butte consists of: (i) reports of stone circles (a/k/a tipi rings) being observed at the site by past visitors, (ii) the identification of possible stone circles in the survey conducted here, and (iii) lithic scatters, consisting primarily of small flakes consistent with late-stage tool manufacture and maintenance, recorded by surveyors in the same general area as the reported stone circles.

As previously discussed, three past visitors to Flattop Butte have reported observing stone circles in the far southwest portion of the butte. E. B. Renaud, the first professional archaeologist to visit the site in 1930, described it is as a "camp-site with tipi-rings, quarry and workshop" (1932:24). In his field notes, he described the campsite as being "large," consisting of "many tipi rings several still visible," estimated to be "6 to 8 paces across," located "near [the] south end" of the butte (Renaud 1930:31). Similarly, in a 1981 letter to the director of the Fort Morgan Museum, Milton Wilbur, a former resident of Logan County, reported visiting Flattop Butte as a boy in 1919 and observing an "Indian village" consisting of "not less than 20 teepee (sic) rings with a fire stone" located "at the southwest corner" of the butte (Wilbur 1981:1). Finally, Richard Jensen, an archaeologist with the Nebraska State Historical society, reported visiting the site in 1971 and observing five stone circles, ranging in diameter from 14 to 18 feet, near the southern edge of the butte (1973:198).

Although debate continues regarding the function of stone circles, most are understood to be the remains of tipi habitations, conical, portable structures made from wooden poles and animal hides, with the hides held to the ground by stones placed at their edges (Davis 1983). Metcalf et al. excavated four stone circles at the Kremmling lithic quarry in the Southern Rocky Mountains of Colorado and interpreted them as habitations (1991:37). Stone circle sites in northeastern Colorado, where Flattop Butte is located, have been dated to between 2000 and 150 calibrated years before the present, although earlier Archaic period and Paleoindian period examples have been documented in the Northwestern Plains of Alberta and Wyoming (Long 2011; Meeker 2017; Morris et al. 1983).

As previously discussed, six possible stone circles were identified in the course of the survey conducted here (Figure 23). These consist of small collections of limestone cobbles, larger than typical limestone materials in the immediate surroundings, in groups from four to ten, spaced such that they could possibly have once been part of a stone circle. All were located in the far southwest portion of the butte, consistent with Renaud's (1930), Jensen's (1973), and Wilbur's (1981) descriptions.

Additional evidence for possible habitations on Flattop Butte comes from five, "very-low" volume lithic scatters, consisting primarily of small flakes, recorded by surveyors in the far southwest portion of the butte, in the vicinity of the possible stone circles (Appendix K). These lithic scatters represented the highest volume debris areas in their 60 x 60 m survey units. They consist entirely of small, thin flakes that appear to be the result of final reduction of quarried material and/or tool making. At the Kremmling quarry, Metcalf et al. observed that habitation areas were characterized by low amounts of lithic reduction debris, consisting primarily of flakes reflective of late-stage tool manufacturing and maintenance (1991:73, 94). Of note, the five very-low volume lithic scatters located at the southwest end of the butte are distinct from the other very-low volume debris examined in the survey at other locations on the butte, which are characterized not by thin flakes but rather by small amounts of irregular chunks and larger flakes of reduction debris.

Finally, the recovery of burned bone, charcoal, scrapers, and an abrader in the quarry pit excavation, as discussed in Chapter Four, suggests the possibility of habitation, rather than simply work-site provisioning, at or near this extraction location. However, the fact that the lithic extraction activities carried out at this location appear to have been highly time and labor intensive, as discussed in Chapter Seven, undercuts this possibility because work of this nature would be expected to be conducted in a logistically organized way, with habitations being located away from extraction locations (Ahler 1986:107-108; Fritz 2021; Gardner 1977; Metcalf et al. 1991:94-98).

Activity Types

Given that the physical evidence for habitations on Flattop Butte is sparse, little can be said about the activities that may have taken place at these locations other than generalities (eating, sleeping, food preparation, etc.).

Locations and Spatial Relationships

All of the possible stone circles and all five of the very-low volume debris areas characterized by thin, tool manufacturing and maintenance flakes were located south of the lithic extraction and lithic reduction zones described above, at the far southwest portion of the butte (Figure 67).

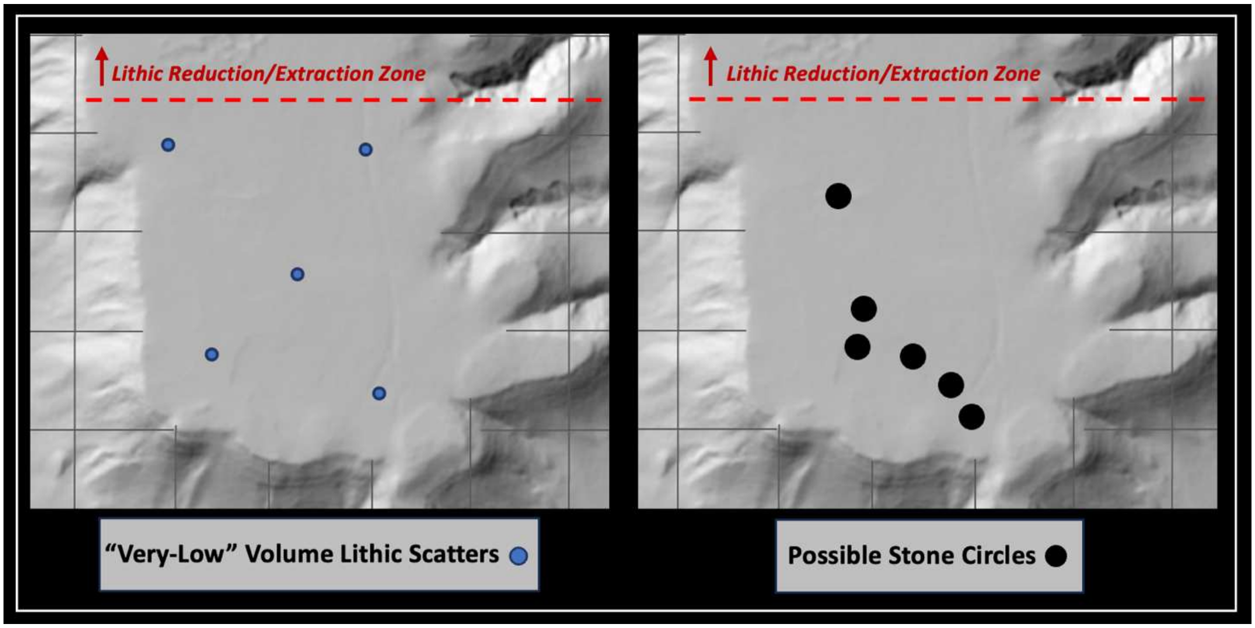

Figure 67. Locations of very-low volume lithic scatters, and possible stone circles.

This is the same area identified by past investigators as the location of stone circles. Accordingly, the southernmost portion of the southwest peninsula of Flattop Butte is designated here as the habitation zone[33] (Figure 68). Consistent with observations at other quarry sites (Ahler 1986:107-108; Fritz 2021; Gardner 1977; Metcalf et al. 1991:94-98), the location of possible habitation areas at Flattop Butte reflect a segregation of living spaces away from production areas.

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[33] Designation of this area as the habitation zone is not intended to suggest that habitations were not present at other locations at Flattop Butte at any point in its long history of use as a lithic source. Rather, it simply denotes that all of the evidence recovered in the survey conducted here suggesting habitations comes from the habitation zone.

Figure 68. Habitation zone.

Overview

As illustrated in Figure 69, evidence gathered in the survey of Flattop Butte suggests three distinct activity zones: (i) a lithic extraction zone, defined by the extent of quarry pit locations, (ii) a lithic reduction zone, defined by the extent of possible secondary lithic reduction workshops, and (iii) a habitation zone, defined by the extent of stone circles and lithic scatters reflecting domestic activities. While the extraction zone is completely overlapped by the reduction zone, this is to be expected as secondary reduction workshops are typically located in the general vicinity, but at a limited distance from, quarry pit locations (Ahler 1986:Figure7; Metcalf et al. 1991:Figure5.2). The significance of these segregated activity locations to the mobility patterns of the groups that operated within them is discussed in the following chapter.

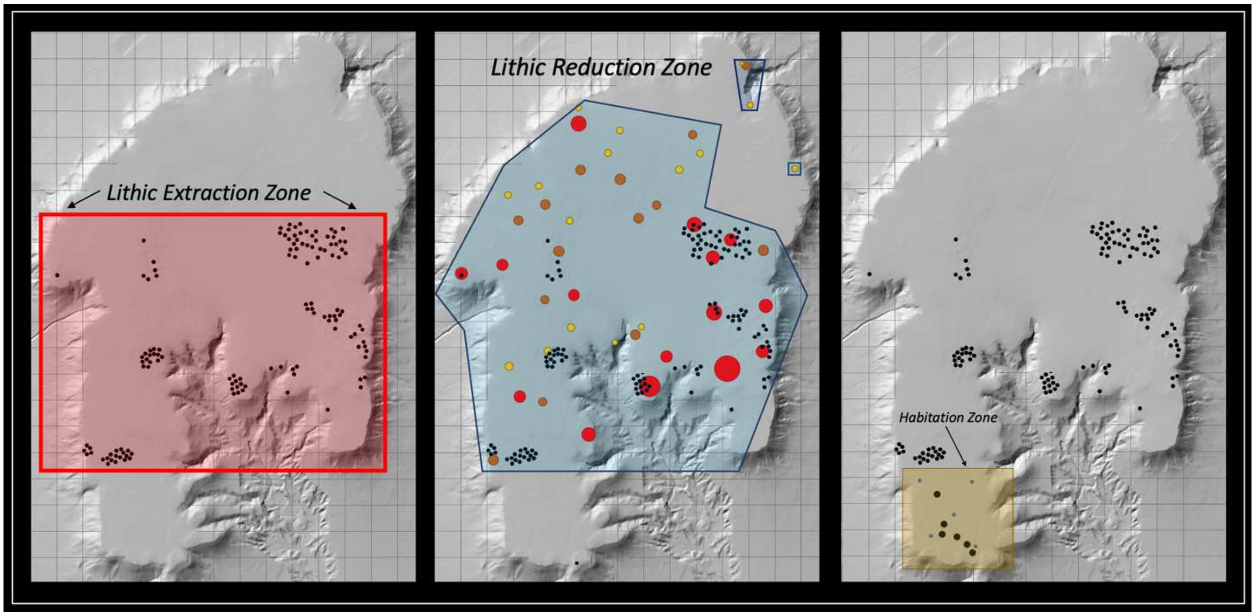

Figure 69. Locations of lithic extraction zone (left), lithic reduction zone (center), and habitation zone (center).

CHAPTER 7 – MOBILITY (EMBEDDED VS. DIRECT PROCUREMENT)

Theoretical Background

As previously mentioned, archaeologists studying hunter-gatherers have focused on the patterns of mobility employed by such groups in acquiring necessary resources as an important means of understanding the processes that shape the contents and spatial patterning observed in archaeological assemblages (Binford 1980). As explained by Binford in his seminal paper on the topic, hunter-gather sites are not all the same, and their variation should relate to their organizational roles within a group's overall settlement/subsistence system (1980).

More specifically, Binford proposed two systems of resource procurement that could be expected to produce different patterning in the archaeological record. The first of these is termed the "forager" system, in which highly mobile groups "map onto" resources by making a series of frequent, annual moves among concentrated resource "patches" (Binford 1980:5). Foragers range out from their residence on a daily basis to procure resources and then return to camp the same afternoon or evening to consume the resources with the group. The second settlement/subsistence system identified by Binford is termed the "collector" system, in which less mobile, more logistically organized groups establish seasonal, central base camps in areas with more dispersed resources, and then send out specialized task groups to distant locations to acquire resources in bulk and return them to the Central base for consumption (Binford 1980:10). Binford's graphical depiction of the differences in the mobility patterning created by forager and collector groups can be seen in Figure 70.

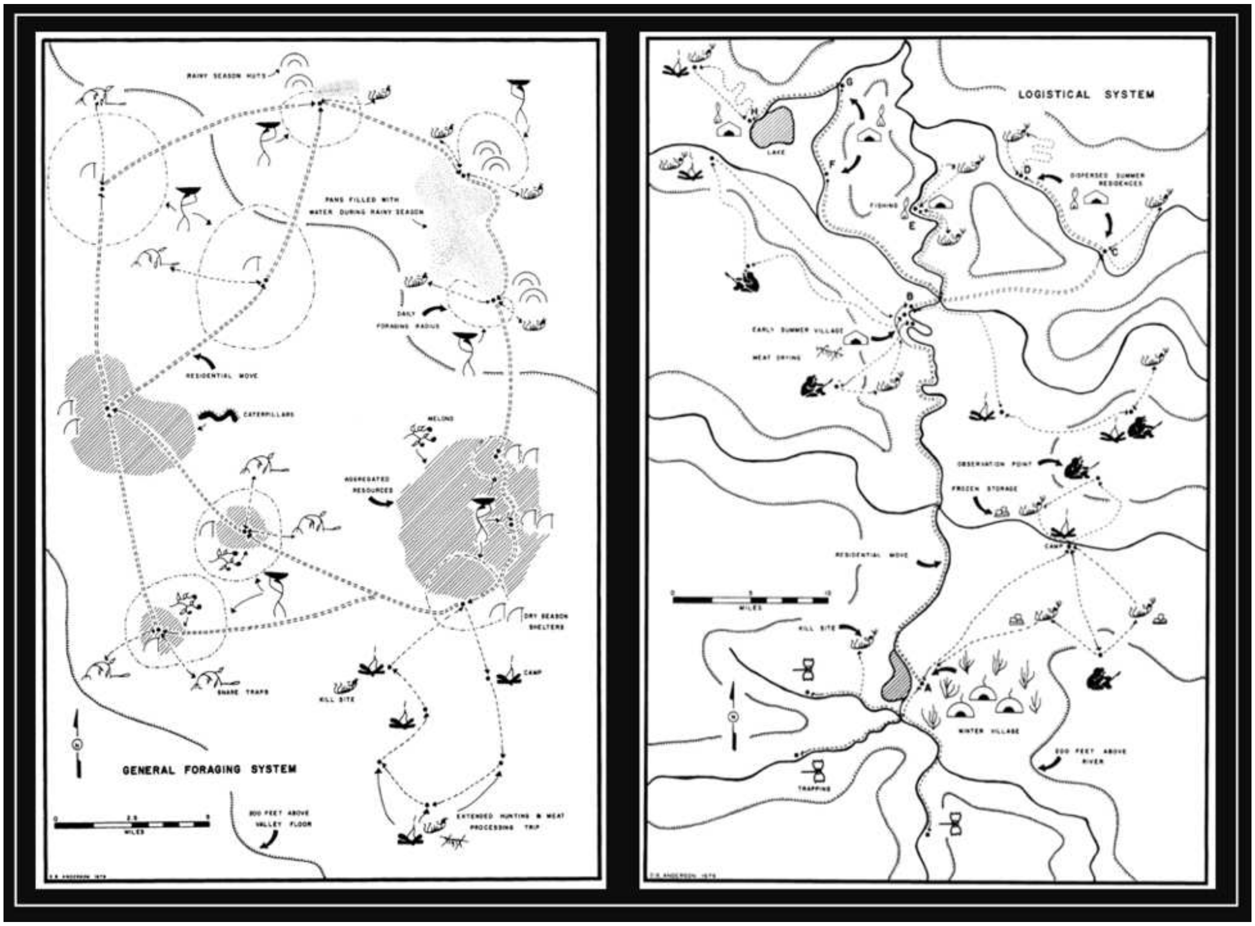

Figure 70. Illustrations of Binford's forager and collector mobility systems. From Binford (1980:Figures 1, 2).

Under the forager/collector model, it is expected that groups employing these different strategies will produce different archaeological assemblages reflecting the differences in the patterning of their organization. Foragers are expected to produce two site types: (i) "residential bases," the Central hub of subsistence activities from which foraging parties depart and return with resources, and the location where the majority of processing, manufacturing, maintenance, and consumption takes place; and (ii) "locations," places away from camp where resources are procured for return to the residential base (Binford 1980:9). Collectors are also expected to produce residential bases and locations, as well as three additional site types: (i) "field camps," temporary operational centers where task groups reside and maintain themselves during procurement forays away from the Central residential base; (ii) "stations," information gathering locales, such as viewshed locations, ambush locations, or hunting stands; and (iii) "caches," temporary storage locations where resources acquired in bulk by task groups are stored, usually pending transport back to the residential center (Binford 1980:10-12).

With regard to the procurement of raw materials, and in particular lithic raw materials, Binford proposed two models of mobility that correspond with his distinction between forager and collector systems: "embedded" and "direct" procurement (1979:259). In the embedded system, foragers move from food patch to food patch, gathering lithic materials along the way, with lithic acquisition having little effect on their mobility and imposing little direct cost because it is *embedded* in other subsistence tasks (1979). In contrast, groups employing a direct procurement strategy establish a Central residential based and move logistical task groups *directly* to lithic sources "for the expressed and exclusive purpose of obtaining lithic raw materials" (Binford 1979:260). These groups must arrange their movements around these forays, and incur the costs associated with them. In contrast, groups employing an embedded strategy acquire lithic raw materials "incidentally to the execution of basic subsistence tasks," meaning "if everything goes well" the acquisition of tool stone has little or no effect on their mobility patterns and imposes "few or no direct costs" (Binford 1979:259).

Binford proposed that hunter-gatherers would normally employ an embedded strategy for the acquisition of lithic raw materials, and would "very rarely, and then only when things have gone wrong" engage in direct procurement (1979:259). While not expressly stated, Binford's view that hunter-gatherers would only rarely engage in direct procurement of lithic raw materials implicitly assumes that these materials would be sufficiently abundant in a group's territorial range to allow for incidental, embedded procurement in the course of mapping onto other resource patches (1979, 1980). This point was made explicitly by Gould (1978) who argued that circumstances of resource availability and quality can make embedded procurement of lithic raw materials difficult if not impossible and could instead require the deployment of logistical task groups over long distances, at significant costs.

Evidence and Expectations from Other Quarry Sites

Given the impact of lithic raw material acquisition on hunter-gatherer mobility patterns, it is not surprising that archaeologists investigating lithic quarry sites have focused on the question of whether the groups that acquired raw materials at these locations were foragers engaged in embedded procurement, or collectors engaged in direct procurement (Ahler 1986; Bamforth 2007; Franklin 2001; Lepper et al. 2001; Metcalf et al. 1991; Reher 1991; Root 1992). Specifically, these investigators have considered the extent of logistical organization engaged in by quarrying groups as displayed in the segregation of activity areas at the site, as well as the time and labor required to extract raw materials given the nature of the lithic deposits being exploited.

For example, at the Kremmling quarry, Metcalf et al. (1991) examined the question of embedded versus direct procurement by looking at the size, nature, and distribution of activity areas, and stages of lithic reduction at quarry pits and an adjacent stone circle. These researchers reasoned that if the groups operating at the site were logistical collectors engaged in direct procurement, it would be expected that they would have left patterns showing a clear segregation of work and domestic areas, with primary knapping occurring outside of domestic areas, and finished tool maintenance and use occurring within them (Metcalf et al. 1991:95). These patterns were expected to be absent if the groups operating at the quarry were highly mobile foragers engaged in embedded procurement (Metcalf et al. 1991:96).

Similarly, at the Knife River flint quarry, Ahler (1986) looked for segregated activity areas as evidence of direct procurement. Quarry pits were identified on the basis of deep subsurface prehistoric excavations, secondary reduction workshops were distinguished by high volumes of secondary reduction debris located at a distance from quarry pits, and habitations were identified based on the presence of pottery, bone debris, fire-cracked rock, and the remains of tool maintenance (Ahler 1986:107-109).

In addition to considering the segregation of activity areas, researchers at quarry sites have also considered the time and labor investment required to extract lithic materials as offering evidence relevant to the question of direct versus embedded procurement. Direct procurement would be expected to involve a significant, organized effort by a substantial work force, as opposed to embedded procurement, which would be expected to involve less significant expenditures of time and labor as lithic materials were acquired "incidentally to the execution of basic subsistence tasks" imposing "few or no direct costs" (Binford 1979:259). As Root has explained it, "increased investment in labor per quarrying episode corresponds with increasing organization in production" (1992:261). Consistent with this principal, Ahler found that the significant labor investment required to dig the larger quarry pits at the Knife River flint source, some extending as deep as 310 cm below the surface, were more consistent with logistically organized direct procurement rather than opportunistic embedded procurement (Ahler 1986:32, 107).

Similarly, at the Windy Ridge quartzite quarry Bamforth observed that the lithic extraction techniques employed there were labor-intensive, requiring the removal of several meters of bedrock over large areas and the excavation of a network of trenches to reach the desired material, which suggested direct procurement by logistical collectors (2007). However, Bamforth also noted that lithic materials from the site were not transported or used over a significant range,[34] suggesting an embedded procurement strategy in which prehistoric peoples arrived at the site and procured lithics for use in the immediate area (2007). Based on this conflicting evidence, Bamforth argued that a hybrid strategy was likely in use at the site, in which lithic acquisition was embedded in the normal subsistence rounds in a limited area, and did not require special trips to the quarry by logistical groups, but that the intensive efforts undertaken to extract lithic materials at the site demonstrate that this was hardly a cost-free exercise (2007).

At the 3rd Unnamed Cave chert quarry in Fentress County, Tennessee, Franklin (2001) also considered the time and labor required to extract lithic materials as offering evidence of embedded versus direct procurement occurring at the site. There the lithic source is located in the deep, dark zone passages of a cave 1000 m from the entrance, where chert nodules were mined and reduced (Franklin 2001). The difficulty of obtaining these materials, and the logistical organization required to do so, led Franklin to conclude that the groups operating at these locations were engaged in direct procurement (Franklin 2001).

Finally, at the Spanish Diggings quarry in east-Central Wyoming, Reher (1991) also considered the question of direct versus embedded procurement in light of the efforts required to quarry tool stone at that location. Based on the depth of carefully back-filled quarry pits and trenches that he observed at the site, Reher concluded that they would have required "a degree of planning and development that is not the sort of casual, sporadic activity envisioned for 'embedded' strategies" (1991:278).

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[34] To determine the geographic extent of the use of Windy Ridge quartzite, Bamforth conducted a literature review of known sites with this material in their assemblages (2007).

Accordingly, the question of embedded versus direct procurement at Flattop Butte is addressed hereafter, first, by considering the availability of lithic resources in the Central plains, the backdrop against which all mobility decisions would necessarily be made, and then by considering the evidence adduced in the survey and excavation conducted here relating to segregation of activity areas and time and labor investments required to quarry lithic raw materials at the site.

Availability of Lithic Resources in the Central Plains

Holen (2014) conducted a comprehensive analysis of lithic sources in the Central Plains, as well as sources in surrounding regions from which lithic resources were transported into the Central Plains (Figure 71). He described the Central Plains as an area where a limited number of relatively well-known and distinct lithic sources are separated by large areas with few or no available materials. (Holen 2014). Naze (2006:295-338) also conducted a detailed investigation of lithic sources in the Central Plains and surrounding regions, including a number of smaller secondary sources, such as river gravels and silicified wood deposits, and concluded as did Holen that high-quality sources in the region are widely separated (2006:338).

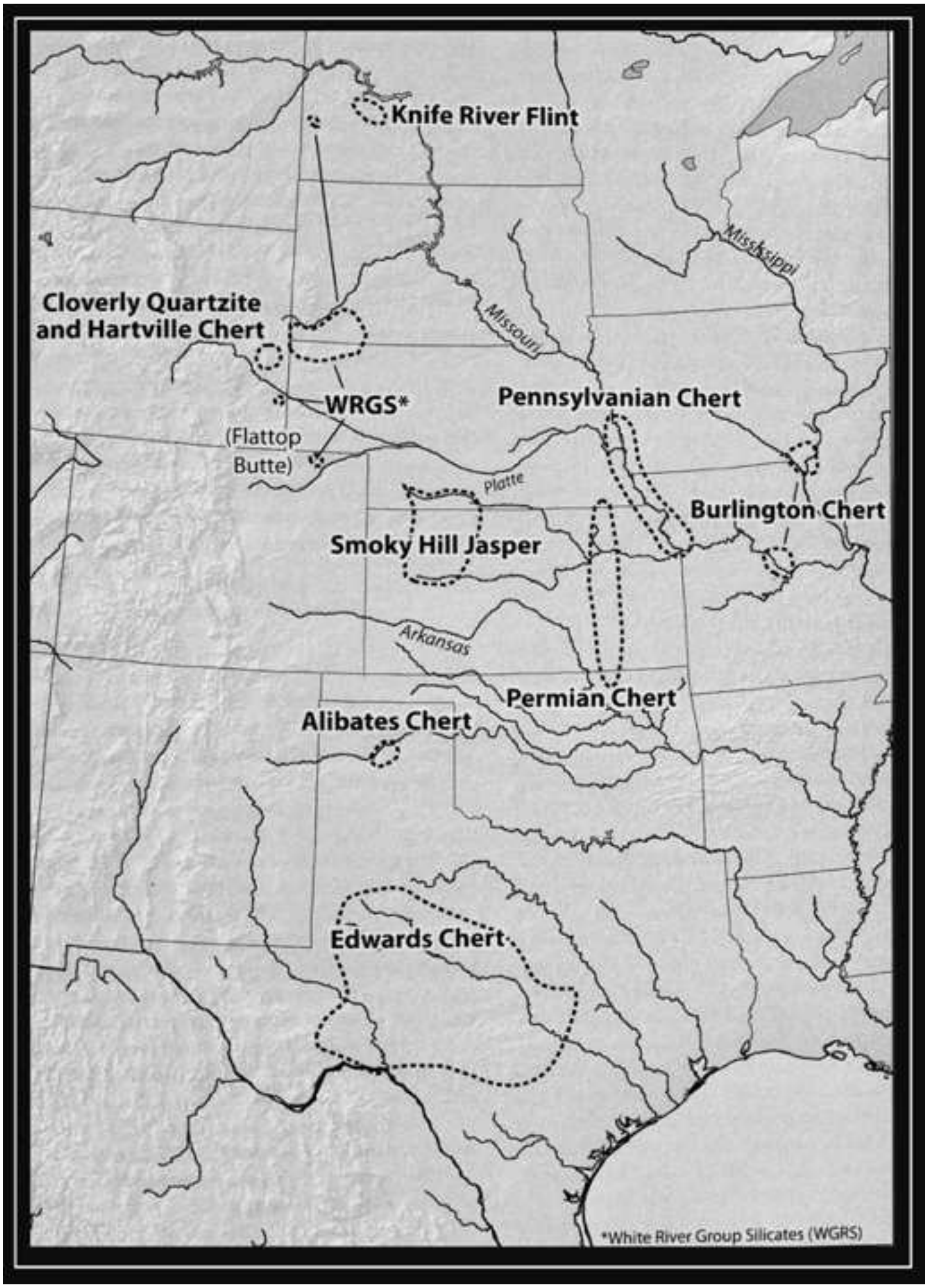

Figure 71. Major lithic sources in the Central Plains and surrounding regions. From Holen (2014:Figure 10.3).

For example, Flattop Butte is the only major bedrock source of high-quality lithic material between western Kansas to the east and the Rocky Mountains to the west, although lithics in cobble form do appear intermittently at other locations (Holen 2014; Naze 2006: 295-338). The closest other major source of lithic raw material is approximately 250 km to southeast of Flattop Butte, where Smoky Hill Silicified Chalk (SHSC) (a/k/a Republic River jasper, Niobrara jasper) outcrops in stream drainages in southwest Nebraska and northwest Kansas (Figure 71) (Stein 2005). Groups operating in the Central Plains also imported lithics materials from sources outside the Central Plains over a region that extends north/south from western North Dakota to Central Texas, and east/west from southeastern Iowa and Central Missouri to eastern Wyoming, encompassing eleven major lithic sources (Figure 71) (Holen 2014).

This environment of widely separated major lithic sources, creating vast areas between with little or no high-quality material, necessitated frequent imports from surrounding regions, and made the Central Plains a challenging environment for lithic acquisition. Groups operating in this region that wished to embed lithic procurement in their seasonal rounds, rather than deploy logistical task groups to acquire these resources, would be required to significantly limit their mobility, carry large amounts of lithic materials with them in their seasonal rounds, or both.

Evidence from Flattop Butte

The survey and excavation work carried out here sheds some (albeit limited) light on the question of whether groups acquiring lithic raw materials from Flattop Butte were engaged in embedded or direct procurement as envisioned by Binford (1979). Specifically, as discussed in Chapter Six, evidence gathered in the survey suggests the presence of three general zones of activity on the surface of Flattop Butte: (i) a lithic extraction zone, defined by the location quarry pit locations, (ii) a lithic reduction zone, defined by the location of secondary reduction workshop locations, and (iii) a habitation zone, defined by the location of possible stone circles and lithic scatters more consistent with domestic functions than lithic production (Figure 66). Consistent with expectations for direct procurement activities at quarry sites (Ahler 1986; Metcalf et al. 1991), the evidence for possible habitation locations at Flattop Butte was all located at a distance from quarry pits and workshops, in the far southwest portion of the butte (Figure 65).[35] While quarry pits and possible secondary reduction workshops are both located in the same general area, at the center portion of the butte, secondary reduction workshops are located at a distance from the nearest quarry pit location (Figure 62), consistent with expectations for direct procurement of lithic resources (Ahler 1986; Metcalf et al. 1991).

This evidence suggests that certain groups at certain times procured lithics at Flattop chalcedony in a direct fashion, making use of logistical task parties deployed from distant residential bases. It does not, however, mean that all groups, at all times, working at all locations on the butte were engaged in direct procurement. Chronological data, linking different activity locations to different periods, is necessary if any inferences are to be drawn about when and where direct versus embedded procurement took place at Flattop Butte.

In addition to evidence regarding the segregation of activity areas, evidence regarding the time and labor involved in extracting lithic materials from the buried limestone caprock was obtained from the excavation unit in a quarry pit carried out here in quarry pit Cluster B. This evidence demonstrates that significant amounts of time, labor, and organization would have been required to quarry Flattop chalcedony at this particular location, consist with expectations for direct procurement (Ahler 1986:32, 107; Bamforth 2007; Franklin 2001). However, this evidence

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[35] As previously noted, the survey conducted here was limited to the surface of the butte, and therefore would not have produced evidence of habitations in the surrounding areas. It is likely that any extended quarrying activity at Flattop Butte would have been based at habitations located closer to the nearest water source, the spring-fed Darby Creek, approximately 2 km east of the butte. Indeed, local private collections appear to indicate multiple campsites in the area surrounding Flattop Butte (Mike Toft, personal communication 2023).

relates only to quarrying activity at this single location during a limited time and cannot be extended to draw inferences about all quarrying, at all times, at all locations on the butte.

Finally, evidence regarding the extent to which Flattop chalcedony was used, and the distances over which it was transported, by ancient groups at different periods can shed light on the question of whether and when lithic procurement at Flattop Butte was carried out in a direct or embedded manner. As discussed in Chapter Five, the literature review conducted here indicates that the use and long-distance transport of Flattop chalcedony varied dramatically over time. As such, this off-site evidence can be combined with on-site evidence to provide additional insight into how mobility/subsistence strategies were impacted by lithic acquisition at Flattop Butte.

Accordingly, the evidence gathered here regarding the question of embedded versus direct procurement is separated into chronological units. Specifically, for each of the Paleoindian period, the Archaic period, and the Late Prehistoric period, evidence regarding segregation of activity areas, time, labor, and organization required to extract lithic materials from quarry locations, and the off-site use and transport of Flattop chalcedony are considered in order to attempt to draw inferences about where and when embedded and/or direct procurement of lithic resources occurred at Flattop Butte. Admittedly, the use of such large time periods, spanning thousands of years, to distinguish differences in mobility patterns that could vary substantially over years, decades, or centuries is imprecise and suggests long-term commonalities that may never have existed. Unfortunately, the data produced by this project, while in many cases the first of its kind for Flattop Butte, does not allow for more fine-grained analysis.

Paleoindian Period Evidence

The evidence relevant to Paleoindian period lithic procurement practices at Flattop Butte begins with a temporally diagnostic Agate Basin projectile point, dating to between 12,500 and 11,500 calibrated years before the present (LaBelle 2005:Table 2.1), found in the middle of a high-density debris area in survey Unit 91 (Figure 55), which is interpreted here as a possible secondary reduction workshop. This possible workshop, consisting of around 800 cm^3 (2.1 kg) of chalcedony flakes and chunks concentrated in a 1 m^2 area, is located approximately 75 m from the nearest quarry pit, and 125 m from the nearest quarry pit cluster (Figure 72). The presence of an Agate Basin projectile point in the middle of the reduction debris suggests that this secondary reduction workshop may date to the Paleoindian period.

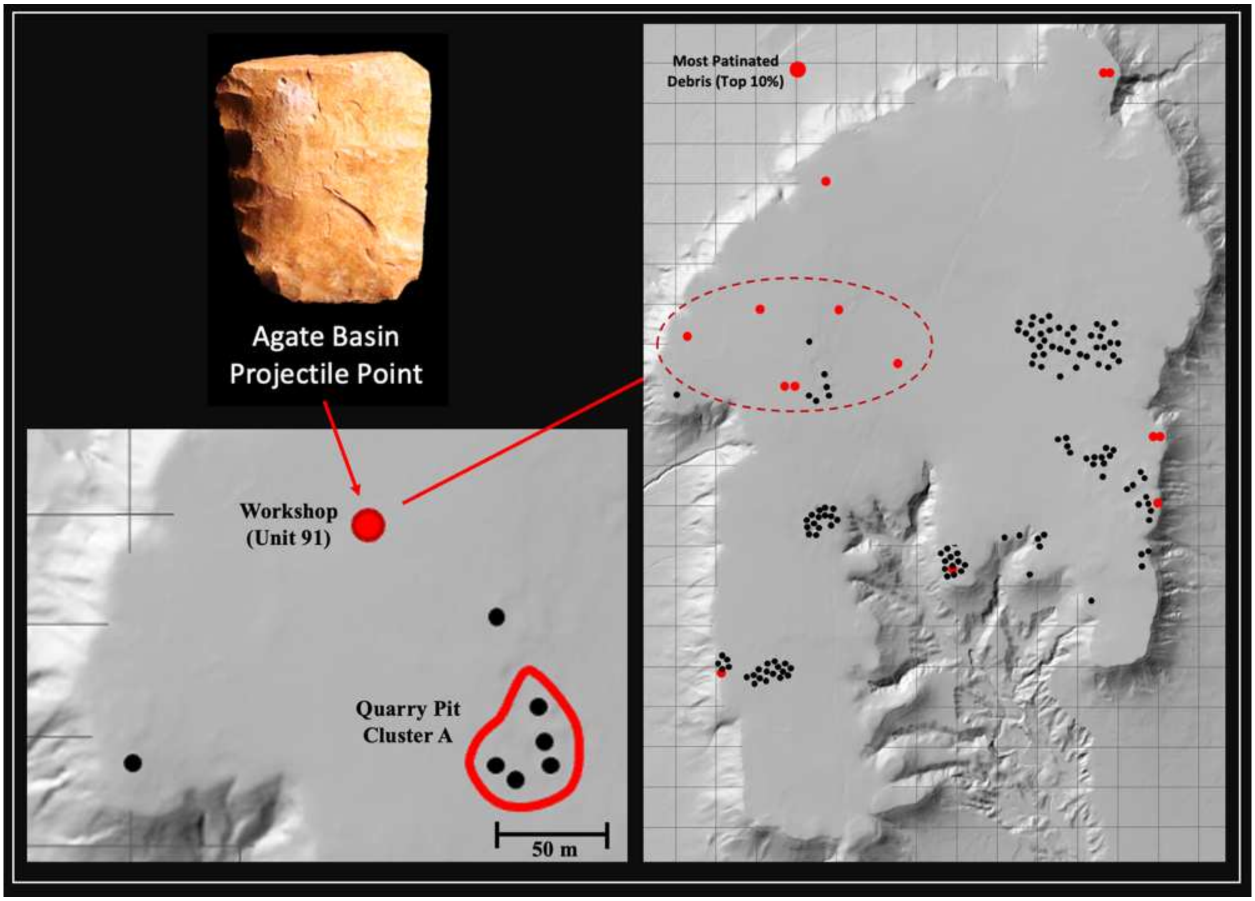

Figure 72. Paleoindian period projectile point, associated workshop, and location of most patinated objects.

Additional support for a Paleoindian period date for this possible secondary reduction workshop comes from patination data. As discussed in Chapter five, Reduction debris in this location displayed the highest concentration of heavily patinated chalcedony debris of any of the 78 high-density debris locations examined, suggesting an early date for this location. In addition, as shown in the right panel of Figure 73, of the top 10% (n = 14) of all patinated chalcedony objects recovered from Flattop Butte, 43% (6 of 14) are found in five possible secondary reduction workshop locations (including the Unit 91 workshop with the Agate Basin projectile point) arranged in a roughly oval shape, surrounding and partially encompassing quarry pit Cluster A. The spatial association of these high-patination locations not only adds support for a Paleoindian period date for the possible workshop in survey Unit 91, it also suggests the possibility that quarry pit Cluster A may also be of an early, possibly the Paleoindian period date. Admittedly, the evidence for these associations is sparse and additional data and analysis would be needed to confirm or refute them.

Taken together, this evidence provides some (albeit limited) support for direct procurement of lithic resources from Flattop Butte at in the Paleoindian period, at least at this particular location. As noted above, the segregation of activity areas, and in particular the location of secondary reduction workshops at a distance from quarry pit locations, is consistent with expectations for direct procurement. However, because no evidence of Paleoindian habitations was identified, nothing can be said as to whether such locations were segregated from work areas, as would be expected for groups engaged in direct procurement.

Other, indirect, support for direct procurement of lithic materials at Flattop Butte in the Paleoindian period comes from the literature review conducted here. As discussed in Chapter Five, during the Paleoindian period Flattop chalcedony was heavily exploited and widely transported over long distances (Table 5, Figure 50). Given the limited availability of lithic resources in the Central Plains discussed above, and the apparent high mobility of Paleoindian groups exploiting Flattop chalcedony, it would appear unlikely that these groups were engaged in the type of incidental procurement of lithic resources, for use in the immediate area, as is associated with embedded procurement.

None of this establishes, however, that all or even most lithic extraction at Flattop Butte in the Paleoindian period was carried out by logistical task groups engaged in direct procurement. Indeed, the significant variation in depth at which Flattop chalcedony is apparently bedded at different locations across the butte suggests the possibility that low-cost, embedded procurement of lithic material was more possible, and therefore more likely, in the Paleoindian period than in later periods. As discussed in Chapter Three, the depth of chalcedony deposits encountered at the quarry pit where the CMPA excavation unit was located was dramatically deeper (around 360 cm) than at the quarry pit where the Greiser test trench was located (around 90 cm), meaning that the costs in labor and time required to extract lithic materials at these two locations would be dramatically different. Thus, if it is assumed that ancient quarriers had the skill and ability to locate and exploit the lowest cost (most shallow) extraction locations, and would move on to more costly (deeper) locations only when lower cost ones had been exhausted, then it can be inferred that the earliest groups extracting chalcedony from Flattop Butte in the Paleoindian period would have had access to the lowest cost locations for production, making embedded procurement at least possible.

Archaic Period Evidence

The evidence relevant to Archaic period lithic procurement practices at Flattop Butte begins with a temporally diagnostic Duncan-Hanna dart point dated to between 5700 and 2250 calibrated years before the present (Eighmy and LaBelle 1996), located in a debris area in the northern portion of the butte (Figure 73). This debris area is located at a significant distance (180 m) from the nearest quarry pit, which is consistent with expectations for direct procurement. However, it is not altogether clear that this debris area is secondary reduction workshop. The volume of debris at this location is "low" as compared to other high-density debris areas at the site (Appendix K), suggesting the possibility that it represents the results of a limited, opportunistic reduction episode rather than a dedicated workshop associated with the production of higher volumes of debris.

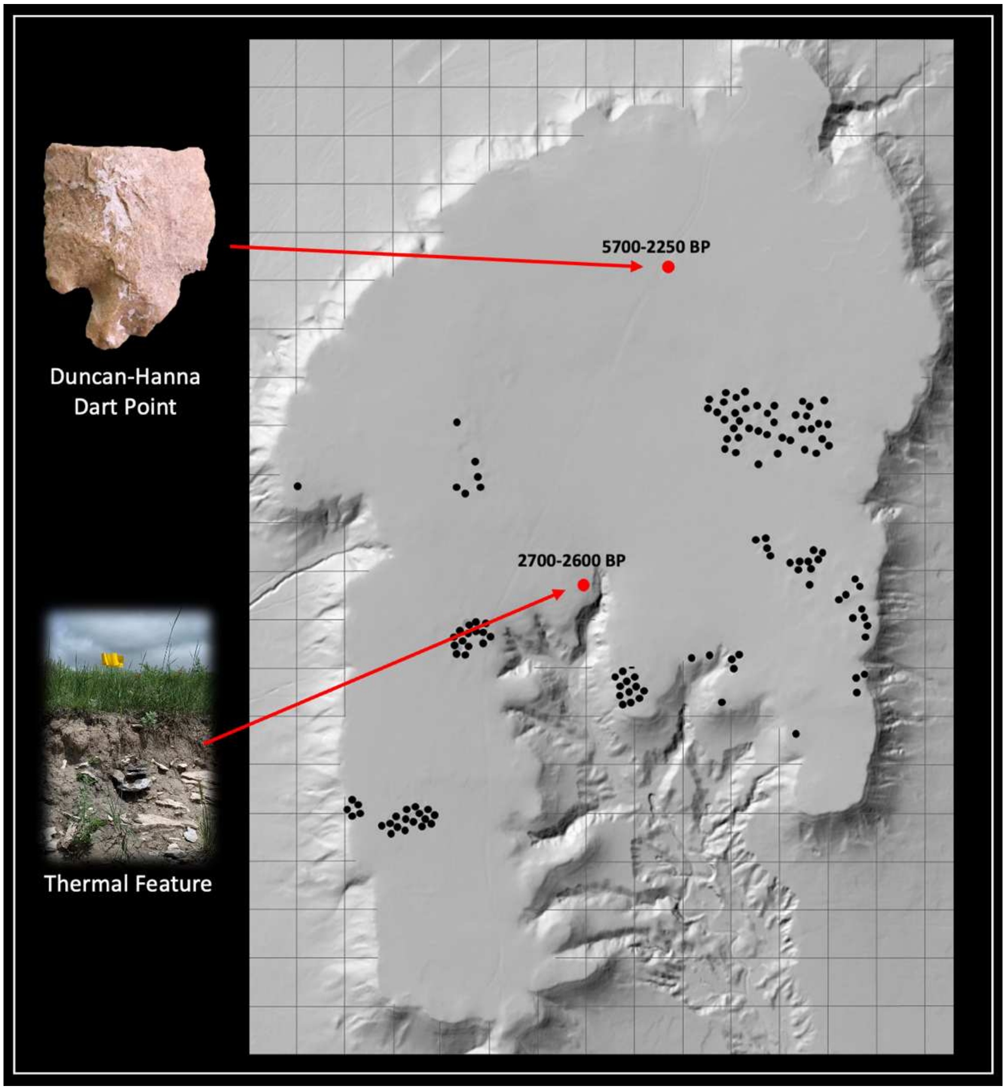

Figure 73. Locations of Archaic period dart point and thermal feature in relation to quarry pit locations.

Additional evidence of Archaic period procurement practices can be found in a buried thermal feature (hearth), found eroding from the western edge of an erosional wash at the south-Central portion of the of the butte (Figure 73), dated to around 2700-2600 calibrated years before the present (Appendix F). As discussed in Chapter Six, it is not clear what activities occurred at this location, although food production is most likely given that the hearth is filled with burned rocks (Troyer 2014). The hearth is also located in an area of medium to medium-high debris density, and is associated with two large pieces of Flattop chalcedony reduction debris, both of which suggest a workshop rather than a habitation. Whatever its function, it is located at some distance from the nearest quarry pit (approximately 90 m), which is consistent with expectations for direct procurement.

The final piece of evidence relevant to Archaic period lithic procurement practices at Flattop Butte comes from the literature review conducted here regarding the use and transport of Flattop chalcedony by ancient groups over time. As discussed in Chapter Five, reported occurrences of Flattop chalcedony during the Archaic period are highly limited in both space and time. Only four reported Archaic period sites were identified. Three of these sites are located less than 50 km from Flattop Butte, and within 55 km of each other, and all likely dating from and after 3500 calibrated years before the present. This apparent contraction in the use of Flattop chalcedony is consistent with the record of most stone tool assemblages recovered in the Great Plains during the Early Archaic period, which are composed largely of locally available raw materials, suggesting a significant reduction in mobility associated with the onset and persistence of drier and warmer conditions in the region from around 8,000 to 4,000 years before the present (Meltzer 1999; Wedel 1986:72). However, as discussed in Chapter Five, there are many reasons to suspect that the literature review under-represents the true use of Flattop chalcedony in the Archaic period, including notably the presence of a significant number of temporally diagnostic Archaic period dart points made of Flattop chalcedony in private collections in the area.

Taken together, this evidence presents a murky, uncertain picture of lithic procurement at Flattop Butte in the Archaic period. The two dated Archaic period locations at the site suggest the possibility of secondary reduction workshops being segregated from quarry pit locations, which is consistent with direct procurement. However, off-site evidence of the use of Flattop chalcedony in this period suggests that its used may have been limited to local, low-mobility groups, a pattern more consistent with embedded procurement. It is also possible that some form of hybrid procurement pattern was employed by groups acquiring lithic raw materials from Flattop Butte in the Archaic period, such as was posited by Bamforth by groups operating at the Windy Ridge quarry, where it was suggested that trips to the quarry were embedded within the seasonal rounds of low-mobility groups who used the material only in the immediate region, but that high labor costs caused by deeply buried deposits meant that lithic procurement was hardly incidental to overall mobility (Bamforth 2007).

Late Prehistoric Period Evidence

The evidence relating to Late Prehistoric period lithic procurement activities at Flattop Butte begins with the quarry pit excavation carried out here in quarry pit Cluster B. As discussed in Chapter Five, this excavation unit produced nine radiocarbon dates and one temporally diagnostic Upper Republican arrow point, all consistent with a Late Prehistoric period date for the extraction of lithic materials at this location. Moreover, as discussed in Chapter Four, the excavation revealed that the Flattop chalcedony deposits at this location were buried around 360 cm below the surface (Figure 36).

As such, before these deposits could be exploited, large volumes of overburden would have to be removed to expose the chalcedony-bearing limestone caprock. For example, in order to expose a 5 m^2 area of caprock at this location, it would be necessary to remove around 90 m^3 of overburden, weighing around 125 metric tons (Table 3). In terms of time and labor, this work would require around 90 person-days of labor to accomplish,[36] such that a team of 10 laborers working full time on overburden removal would be required to devote nine full days just to this task. As illustrated in Figure 74, this is around *ten-times* the volume of overburden removal, and therefore *ten-times* the labor, as would have been required to expose an equal amount of chalcedony-bearing caprock at the Greiser test trench location in quarry pit Cluster C (Table 3).

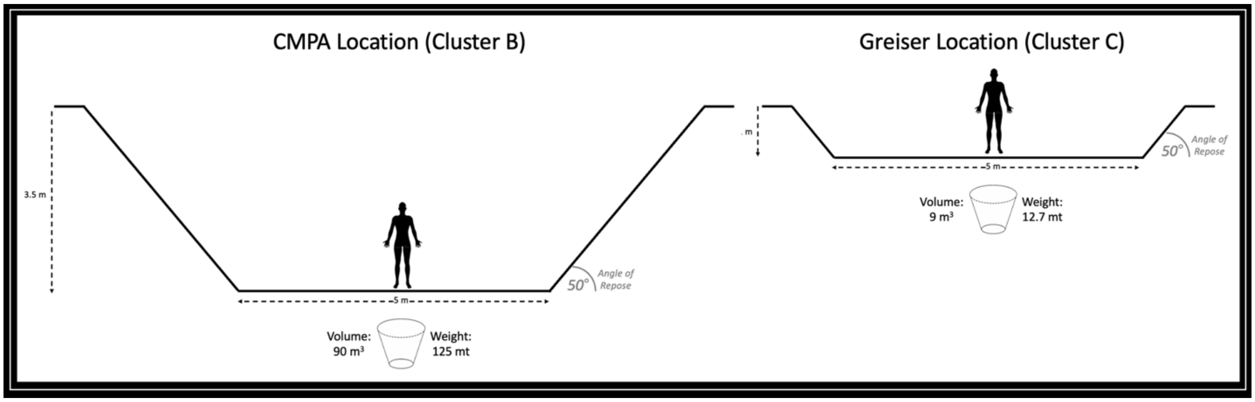

Figure 74. Comparison of overburden removal required to expose 5 m^2 of chalcedony-bearing caprock at CMPA excavation location in quarry pit Cluster B and Greiser test trench location in quarry pit Cluster C.

Labor demands of this magnitude are plainly inconsistent with lithics being acquired "incidentally to the execution of basic subsistence tasks ... with no extra effort expended in the procurement" such as Binford describes for embedded procurement systems (1979:259, 269). Rather, it appears clear that at the quarry pit area excavated here, lithic extraction in the Late

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[36] An estimated removal rate of 1m^3 of overburden per worker per day, derived by Ahler for use in estimating lithic extraction labor costs at the Knife River flint source area (1986:82), is used here. This rate is generally consistent with commercial estimates for the labor required for manual soil excavation (TheProjectEstimate.Com 2023).

Prehistoric period required significant planning, well-organized efforts, and the expenditure of great amounts of time and hard physical labor, all of which strongly imply direct procurement by large logistical task groups.

Additional support for direct procurement in the Late Prehistoric period at Flattop Butte comes from the evidence of stone circles in the habitation zone at the far southwest portion of the butte. As discussed in Chapter Three, as many as 20 stone circles were observed in this area by numerous visitors to the site between 1919 and 1973 (Jensen 1973; Renaud 1930:31; Wilbur 1981), and the survey conducted here identified six possible stone circles in the same general area. While no dating is available for these features, stone circle sites in the northeastern Colorado have been dated to the Late Prehistoric period (Long 2011; Meeker 2017; Morris et al. 1983). The location of these habitations in the far southwestern portion of the butte, segregated at a significant distance from both quarry pits and secondary reduction workshops, is consistent with direct rather than embedded procurement (Ahler 1986; Metcalf et al. 1991).

Finally, the extent of use and transportation of Flattop chalcedony in the Late Prehistoric period, as revealed in the literature review conducted here, also support direct procurement of lithic resources at Flattop Butte at this time. As discussed in Chapter Five, the use and long-distance transport of Flattop chalcedony in the Late Prehistoric period rebounded sharply from the declines seen in the preceding Archaic period. Flattop chalcedony has been reported at 11 Late Prehistoric period sites associated with six identifiable cultural complexes (Table 5), extending over an area approximately 400,000 km^2 (Figure 52). Similarly, Flattop chalcedony has been observed to have been utilized extensively by Late Prehistoric, Upper Republican groups operating over long distances in and around northeastern Colorado (Wood 1967) and south-Central Nebraska (Wedel 1986:111). This evidence of widespread use and long-distance transportation of Flattop chalcedony in the Late Prehistoric period is more consist with the direct procurement of large quantities of lithic materials rather than incidental embedded procurement by low-mobility groups using the material only in the immediate vicinity of Flattop Butte.

Taken together, this evidence suggests direct procurement of lithic materials at Flattop Butte in the Late Prehistoric period, particularly at the quarry pit location excavated here in quarry pit Cluster B. However, broader trends are present which suggest that direct procurement may have been the dominant means of acquiring Flattop chalcedony in the Late Prehistoric period. The wide-spread, long-distance transport of lithic materials from Flattop Butte in this period certainly points in this direction. Moreover, the depth of deposits encountered in the excavation unit in quarry pit Cluster B suggests that 12,000 years of quarrying at Flattop Butte had exhausted more shallow, easier to extract, deposits of high-quality Flattop chalcedony by the Late Prehistoric period, making opportunistic, low-cost, embedded procurement of lithic raw materials at the site all but impossible.

CHAPTER 8 – CONCLUSION

This thesis reports on an archaeological investigation of Flattop Butte (5LO34), a prehistoric lithic quarry in the Central Plains of northeastern Colorado, seeking evidence relevant to three fundamental research questions: (i) the chronology of use of the site by ancient groups, (ii) the spatial organization employed by these groups in procuring lithic raw materials at the site, and (iii) the effect of those lithic procurement activities on the mobility patterns of these ancient groups. The results of that investigation with respect to each of these research questions are summarized hereafter, followed by suggestions for future work to follow up on and advance the findings made here.

Chronology

As discussed in Chapter Five, the first research question posed here relates to chronology, and asks when was Flattop Butte used as a lithic source by ancient groups in the Central Plains and beyond, and when were particular locations at the site used by these groups to extract and process Flattop chalcedony? The first source of information relevant to these questions comes from locations away from the site, where Flattop chalcedony was transported and used by ancient groups to make stone tools. The literature review conducted here demonstrates that Flattop chalcedony was used continuously for over 13,000 years by ancient peoples in the Central Plains and surrounding regions, from the earliest Clovis groups in the Paleoindian period, through the Archaic and Late Prehistoric periods, until the abandonment of stone tool technology after the time of European contact. Moreover, because Flattop Butte is one of few sources of high-quality lithic materials in the Central Plains, the earliest humans who entered the region, whose presence and timing are as yet shrouded in uncertainty, would almost certainly have sought out, visited, and acquired essential lithic raw materials from the site.

The record of off-site usage of Flattop chalcedony not only reveals the time span over which this material was acquired and used by ancient groups; it also sheds light on the intensity of its use over time. For example, this record demonstrates that significant quantities of Flattop chalcedony were used and transported over long distances (up to 580 km) throughout the Paleoindian period, particularly by early Clovis and Folsom groups in the Central Plains who used Flattop chalcedony more than any other lithic material for making projectile points and preforms. In contrast, the record of off-site usage in the succeeding Archaic period shows an apparent drop-off in the use of Flattop chalcedony and the distances over which it was transported. As for the succeeding Late Prehistoric period, the record of offsite usage of Flattop chalcedony shows a return to widespread usage and long-distance transportation.

While a study of off-site use of Flattop chalcedony can tell us much about when and where this material was ultimately used and transported, it can tell us nothing about when and where on-site, at Flattop Butte itself, these lithics were obtained and processed. The results of the survey and excavation work conducted here shed some limited light on these questions.

From the Paleoindian period, a possible secondary reduction workshop in the northeast portion of the butte was identified. At this location, large volumes of lithic reduction debris (over 2 kg) were found concentrated in a 1 m^2 area, over 75 m from the nearest quarry pit. Included in this assemblage was a temporally-diagnostic Agate Basin projectile point, dating to between 12,500 and 11,500 calibrated years before the present. Also included in this assemblage was reduction debris with the highest levels of patination of any of the 78 high-density debris areas examined across the butte, which suggests an early date for this possible secondary reduction workshop. In addition, the proximity of this Paleoindian workshop to quarry pit Cluster A, together with evidence of high-patination debris being present in other high-density debris areas surrounding Cluster A, suggest the possibility that it may also date to the Paleoindian period.

From the Archaic period, two possible secondary reduction workshops located at a distance from the nearest quarry pits, were identified. The first is located in the northwest portion of the butte, and an Archaic period date is suggested by the presence of a temporally-diagnostic Duncan-Hanna dart point, dated to around 5700 to 2250 calibrated years before the present. The second Archaic period location is a buried thermal feature located in the side of an erosional wash at the south-Central portion of the butte, which may be associated with a secondary reduction workshop. A radiocarbon date on soot from the feature returned a date of between 2700 and 2600 calibrated years before the present.

From the Late Prehistoric period, two locations were identified, a quarry pit, and possible stone circle habitations. The quarry pit is in the center of the largest quarry pit cluster (Cluster B), located in the northeastern portion of the butte. This quarry pit was the location of the excavation project reported here. Radiocarbon dates on nine samples of bone recovered from the pit between 40 and 340 cm of depth returned Late Prehistoric dates, between 1066 and 553 calibrated years before the present. Further confirmation of a Late Prehistoric date for this quarry pit comes from a temporally-diagnostic, Upper Republican arrow point recovered in the quarry pit fill. The other possible Late Prehistoric period location is not a specifically identifiable place, but rather is a broader area, encompassing the far southwest portion of the butte. There, visitors to the site between 1919 and 1973 reported observing as many as 20 stone circles, typically associated with tipi habitations. Possible traces of these stone circles were identified in the survey of the area conducted here, but no dateable material was identified. These possible stone circles are assigned here to the Late Prehistoric period based on the dating of similar features in the South Platte River basin to between 2000 and 150 years before the present

Spatial Organization

As discussed in Chapter Six, the second research question posed here relates to spatial organization, and asks where at Flattop Butte ancient groups carried out their lithic procurement activities, and whether they segregated this work into separate, specialized activity areas. The survey conducted here identified three possible spatially distinct, activity location types: (i) quarry pits, (ii) secondary reduction workshops, and (iii) habitation locations. These findings are consistent with the types of activity locations identified at other quarry sites in North America.

A total of 128 quarry pits were located on the surface of the butte. Virtually all of these pits (124 of 128) are located in seven clearly discernable clusters, located at a distance from each other but confined to the Central portion of the butte. The area encompassing these quarry pit cluster is referred to here as the lithic extraction zone. Evidence recovered in the excavation of a quarry pit in the middle of the largest cluster demonstrates that, at these locations, ancient groups dug down through topsoil (as much as 3.5 meters deep) to reach deposits of Flattop chalcedony that were bedded in the buried limestone caprock of the butte. The quarry pit excavation also revealed that ancient groups carried out initial reduction of the extracted chalcedony in the pits themselves, backfilling exhausted pits with debris and overburden from new exposures. This can be seen in the substantial volumes of reduction debris – nearly 130 kg per m^3 – that were encountered in the fill of the excavated quarry pit, consisting of large slabs of the broken limestone caprock and countless chunks and flakes of chalcedony.

The next possible specialized activity area type identified on Flattop Butte represents the next step in the process of procuring lithics at the site: secondary reduction workshops. These are locations where it appears that large volumes of Flattop chalcedony, which had been uncovered, extracted, and initially tested and processed at quarry pit locations, were moved away to separate locations on the butte for further reduction into forms more suitable for transportation and use away from the site. These locations were characterized by significant volumes of chalcedony flakes and chunks appearing on the surface of the butte in well-defined, roughly-circular concentrations, generally around 1 m^2 in diameter, set off at a distance from quarry pit locations. A total of 35 possible secondary reduction workshops were identified in the survey conducted here, but it is clear that this is only a small fraction of the entire number possibly present on the butte, given that surveyors were only instructed to identify the single highest-density debris area in each 60 x 60 m unit surveyed. The area encompassed by these possible secondary reduction workshops is referred to here as the lithic production zone. This lithic production zone overlaps the lithic extraction zone, with both covering the central portion of the butte, but not extending into the southern portions. Unlike the lithic extraction zone, however, the lithic reduction zone extends into the northern portion of the butte, save for most of the far northeastern portion.

The third and final specialized activity area type possibly present at Flattop Butte are habitation locations. For the most part, the evidence for these locations comes from reports of past visitors to the site, rather than from the work performed here. From 1919 to 1973, visitors to the site (both professional and amateur) reported observing as many as 20 stone circles in the far southwest portion of the butte. Stone circles are typically interpreted as tipi habitation locations. Survey in the far southwest portion of the butte failed to locate clear evidence of stone circles, although collections of limestone cobbles were observed at seven locations in the area that could plausibly have once been part of stone circles. The southwest area of the butte where stones circles were reported, and where the possible stone circles were observed here, is referred to here as the habitation zone. This zone is separate from and does not overlap with either the lithic production or lithic reduction zones discussed above. Significantly, lithic debris in the habitation zone is very sparse compared to other areas on the butte, and is characterized by low-density scatters of small flakes, more consistent with tool manufacture and maintenance than with lithic raw material production.

Mobility

As discussed in Chapter Seven, the final question posed here relates to the effect, if any, that acquiring tool stone from Flattop Butte had on the mobility patterns of the ancient groups that visited the site for this purpose. Specifically, the question is whether these groups were engaged in what Binford (1979) referred to as embedded or direct procurement. Embedded procurement describes the activities of foragers who, in the course of moving from one resource patch to the next, make incidental, short-term stops along the way to gather readily available tool stone. Lithic procurement of this kind is essentially cost-free and has little or no effect on overall mobility patterns. In contrast, direct procurement describes the activities of logistical collectors who establish a more permanent residential base and then send out specialized task parties to acquire needed resources and return them to this Central location. Lithic procurement of this type generally involves significant costs in time and labor incurred in travelling to the lithic source, producing significant quantities of tool stone, and transporting them back to the residential base. For these reasons, direct procurement has a significant impact on overall mobility patterns.

Four lines of evidence developed here bear on the question of whether groups procuring lithic raw materials at Flattop Butte were engaged in embedded or direct procurement. The first is the availability of lithic materials in the Central Plains, the unalterable backdrop that conditioned all mobility decisions in the region. The concept of embedded procurement presupposes that lithic materials will be generally available on the landscape and can therefore be acquired incidentally in the course of moving between other resource patches. This is not the case in the Central Plains, where high-quality lithic sources such as Flattop Butte are few and far between. Indeed, the next closest significant tool stone source, other than secondary cobble deposits (Naze 2013), is at least 275 km to the southeast. This scarcity meant that groups wishing to engage in low-cost, low-volume, incidental procurement of lithic resources from Flattop Butte, would be likely be required to restrict their mobility to the immediate area of the butte.

The second line of evidence bearing on the question of embedded versus direct procurement at Flattop Butte is the extent to which Flattop chalcedony was used and transported by ancient groups, as demonstrated by the appearance of this material in the archaeological assemblages of distant sites. The literature review conducted here of such sites shows that the patterns of use and transport of Flattop chalcedony varied significantly over time. In the Paleoindian period, Flattop chalcedony was a favored tool stone, used in large quantities and transported over long distances. When this pattern is combined with the general scarcity of high-quality lithic materials in the Central Plains, it calls into question whether Paleoindian groups could have engaged in low-cost, incidental lithic procurement at Flattop Butte. In contrast, in the Archaic period, the use and transportation of Flattop chalcedony contracted dramatically, meaning that groups who were already restricting their mobility patterns, and relying more on locally available lithic materials, could have engaged in embedded procurement at Flattop Butte, although doing so may not have been cost-free. Finally, in the Late Prehistoric period, the use and transportation of lithic material from Flattop Butte returned to patterns similar to those seen in the Paleoindian period, with Flattop chalcedony being used in large quantities and transported over long distances, behavior more consist with direct, rather than embedded, procurement.

The third line of evidence bearing on the question of embedded versus direct procurement is the cost, in time and labor, of procuring lithic materials at Flattop Butte, and how that might have varied over time. If large crews working over many days were required to extract Flattop chalcedony from the buried limestone caprock, incidental, low-cost, embedded procurement would not have been an option. Evidence developed here in the excavation of a Late Prehistoric period quarry pit shows that this was exactly the case by this late date, with lithics extracted at this location being buried at a depth of over 3.5 meters. Reaching materials at this depth required the removal of over 60 metric tons of overburden, at a cost over 45 person-days of labor, just to expose the *first* square meter of chalcedony-bearing limestone caprock.[37] Assuming that ancient groups were not simply ignoring or unable to locate other less deeply buried deposits at this time, it is difficult to see how high-cost, direct procurement was not a requirement at Flattop Butte, at least by the time this quarry pit was excavated in the Late Prehistoric period.

However, evidence from a trench placed in a quarry pit in a cluster across the butte, by Greiser in 1973, shows that not all deposits of Flattop chalcedony were so deeply buried. At that location, the chalcedony-bearing caprock appeared at just under a meter of depth, making the cost of procurement there a small fraction of what it was at the Late Prehistoric location excavated here.

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[37] As noted in Table 2, the cost of lithic extraction at this location would remain very high, even after a quarry pit had been opened and reached the chalcedony-bearing caprock, with each additional 1 m^2 area of caprock exposure requiring the removal of an additional 14 m^3 of overburden, requiring roughly 14 person days of labor to accomplish.

Thus, if we assume that ancient peoples had acquired the know-how and skill, over millennia of lithic procurement, to efficiently locate and exploit the lowest cost materials that met their needs, it appears that at least in earlier periods of its use, Flattop chalcedony was available at depths that would have allowed for at least the possibility of embedded procurement.

The final line of evidence bearing on the question of embedded versus direct procurement is the spatial and logistical organization employed by groups procuring lithic raw materials at Flattop Butte. Researchers investigating the question at other quarry sites have developed a set of expectations for the kinds of spatial organization that would be consistent with embedded versus direct procurement. Specifically, incidental, low-cost embedded procurement would be expected to be associated with little or no differentiation of activity areas, because extraction, reduction, and (if even necessary) habitation would be expected to take place in the same, spatially-limited, short-term location. Whereas, high-cost, labor and time intensive, direct procurement would be expected to involve more logistical organization and a separation of tasks into specialized, spatially separated, activity areas: quarry pits, secondary reduction workshops, and habitations. As noted above, evidence suggesting the possibility of all these types of spatially separated activity areas appears at Flattop Butte, although evidence for when these locations were employed is less abundant.

Taken together, these lines of evidence suggest that direct procurement may have been the dominant means of lithic procurement at Flattop Butte, having significant effects on the mobility patterns of groups acquiring Flattop chalcedony there over time. In the Paleoindian period, it was likely possible to procure lithics at the site at relatively shallow depths without incurring significant labor costs, meaning embedded procurement would likely have been possible. But the volumes of Flattop chalcedony used by groups at this time, together with the long distances over which it was transported, and the relative scarcity in the region of other major lithic sources, all suggest that the dominant mode of lithic procurement at Flattop Butte in this period may have been direct procurement.

The picture is somewhat different for the Archaic period when the use and transportation of Flattop chalcedony was far more limited. Given the trend of limited mobility and reliance on local lithic sources by Archaic period groups in the region, it is at least possible that lithic procurement at Flattop Butte could have been embedded in other subsistence related mobility. What is unknown however, is whether there were any shallow, untapped deposits of Flattop chalcedony remaining at this time that would have allowed for low-cost, embedded procurement, or why the two Archaic period possible secondary reduction workshops located here would be placed at such a distance from the extraction location if the goal was incidental, low-cost, embedded procurement.

For the Late Prehistoric period, the picture is somewhat more clear. At this time, Flattop chalcedony was being used in large quantities, transported over long distances, and extracted in a labor-intensive manner from deeply buried deposits at Flattop Butte, where habitations were set off at a distance from production areas. All this evidence points to direct lithic procurement in the Late Prehistoric period, having a significant effect on the mobility patterns of these groups.

Recommendations for Future Work

The archaeological investigation of Flattop Butte reported here is only a start, although some progress has been made on the research questions posed. The following recommendations for future work are made with an eye towards building on this progress and continuing the process of documenting basic information about the site.

Quarry Pit Excavation

One lesson learned from this investigation is that quarry pits contain a wealth of relevant information regarding the questions raised here. Therefore, excavations of more quarry pits are called for. Specifically, it is recommended that an excavation unit be placed in the middle of the centermost quarry pit in each of the seven quarry pit clusters identified here. The units would be of the same size, and excavated and recorded in the same manner, as the excavation unit described here. These excavation units would be expected to produce evidence relevant to: (i) dating, of both the quarry pits themselves and possibly the clusters in which they are included, (ii) labor costs, as reflected in differences in the depth of deposits at different locations, and (iii) quarrying practices, as reflect in debris volumes and types at different locations. In addition, it is recommended that a qualified geologist be consulted to examine the stratigraphy of each quarry pit, with the primary goal of measuring and describing post-abandonment soil formation, for comparison with other locations across the butte.

Coring

The present investigation revealed that the depth at which chalcedony-bearing limestone caprock is buried beneath the surface of the butte varies, and for this reason was a critical factor in the cost of acquiring lithic materials at various locations. Therefore, to gather additional information regarding the differences in caprock depth at each of the quarry pit clusters identified here, it is recommended that coring be conducted adjacent to these locations. Specifically, it is recommended that a ¾” bucket- auger be used to remove soil cores at the north, south, east, and west periphery of each of the quarry pit clusters to determine the depth of the buried caprock at each location.

Follow-Up Survey

The survey conducted here identified secondary reduction workshops in the northern portion of the butte, in areas generally characterized by low to very low debris density, that are located at an unusual distance from the closet quarry pit, suggesting the possibility of undetected quarry pits in the vicinity of these locations. Therefore, it is recommended that an area extending 100 m in each direction from each such workshop be surveyed for any indication of quarry pits.

In addition, patination data suggests that many of the oldest locations on the butte may be located at or near the edges of the butte. Accordingly, it is recommended that a complete survey of the outer 10 m of the surface of the butte be conducted, searching for evidence of quarry pits and workshop locations. It is also recommended that the top levels of the talus apron appearing at the edges of the butte be surveyed, searching for chalcedony deposits or evidence of human activity eroding out of the sides of the butte.

Workshop Excavation and Analysis

High-volume concentrations of quarrying debris on the surface of the butte, averaging around 1m^2 in area and located at distance of more than 25m from the nearest quarry pit, were identified here as secondary reduction lithic workshops. To further test these identifications and gather additional information about these locations, it is recommended that five previously identified workshops be selected for additional testing. Two of these would be the locations where the Paleoindian period Agate Basin projectile point and Archaic period Duncan-Hanna dart point were located. The other three locations would be the highest volume workshops remaining. At each such location, the tests described below would be conducted.

First, the surface debris constituting each workshop would be sorted into the slab/chunk/flake categories used here in connection with the quarry pit excavation and measured separately by volume. Debris recovered in the quarry pit excavation consisted of approximately 52% chalcedony chunks, 29% limestone slabs, and 19% chalcedony flakes. When considering only chalcedony debris, the breakdown was 74% chunks and 26% flakes. These categories can be thought of as representing three stages of lithic extraction and reduction, with slabs resulting from the initial task of breaking through and extracting materials from the limestone caprock, chunks resulting from initial testing and cortex removal of chalcedony masses, and flakes representing initial reduction of materials into more easily worked packets. Based on these findings, it would be expected that secondary reduction workshops, where the next steps in the processing of lithic raw materials would occur, would contain no or low volumes of slabs, and higher volumes of chalcedony flakes than chunks, reversing the pattern found in the quarry pit fill.

Next, a 1 x 1 m excavation unit would be placed at the center of each workshop. These units would be excavated in 10 cm levels to sterile soil. The volume of debris in each level would be measured by type (slabs/flakes/chunks). Consistent with patterns for secondary reduction workshops found at other quarry sites, the expectation would be that these workshops would not extend to significant depths. The stratigraphy exposed by these excavation units would also be examined by the geoarchaeologist engaged to consider soil formation and deposition at the butte.

Finally, in attempt to determine whether these workshop locations extend horizontally, outside of the exposed, roughly circular areas observed, into and beneath the surrounding grass-covered areas, the top 10 cm of grass and soil surrounding each of the five selected workshops in a .5 m radius would be removed and screened, and the volume of debris would be measured by type (slabs/flakes/chunks).

Mapping the Butte

Additional mapping of the surface of the butte is called for. No detailed topographic map of the surface exists, and the quarry pit maps set forth here were produced using hand-held GPS coordinates, and do not include information regarding the area or surface depth of individual pits. This information would be valuable for further analysis of quarrying patterns and techniques, and how these might have changed over time Therefore it is recommended that such maps be produced using drone-based aerial mapping, employing either photogrammetry of high-resolution LiDAR (e.g. Raeva et al. 2021). A plan for producing such maps would have to address a variety of complicating factors, including snow cover in winter, remaining snow in quarry pits and high winds in the spring, and tall grass in quarry pits in the summer and fall, all of which were encountered in previous attempts to produce such maps.

Mapping and Survey of the Immediate Surroundings

The present investigation was confined to the surface of the butte. It is recommended that additional survey and mapping of the areas immediately surrounding the butte be conducted to gain insight into how these areas were used by ancient peoples in connection with their quarrying activities. This survey would be carried out in the same manner as the survey of the butte described here, with a 60 x 60 m grid placed over an area extending 200 m in all directions from the terminus of the talus apron, and approximately 50% of these units selected for survey in a checkerboard pattern. A preliminary reconnaissance of the area to examine the density of cultural remains would determine whether surveyors would be instructed to map and/or examine all, or only the highest density, debris areas encountered.

Survey Darby Creek

It is recommended that the nearby Darby Creek, approximately 2 km east of the butte be surveyed for a distance of approximately 2 km of its north/south run, centered on the Flattop Butte. Darby creek is the nearest perennial source of water to the butte. Based on an analysis of Clovis mobility patterns, Holen has suggested that Flattop Butte "provides one of the best examples of possible band aggregation locations in the Central Plains" (2014:197). If this is so, these groups would likely have made their residential basecamps in and around the nearest source of water (Darby Creek), a pattern that was observed by Gardner (1977) at the Flint Run Paleoindian complex, a Clovis quarry/aggregation site in northern Virginia.

Literature Review to Investigate the Extent of the Flattop Chalcedony Terrane

A prehistoric tool stone's "terrane" is the geographic area over which its use was dominant (Shott 2021). The literature review conducted here addressed where and when Flattop chalcedony appears in off-site archaeological assemblages, but did not consider other tool stones, from other sources, used at these same locations. Nor did it consider the extent to which Flattop chalcedony was more widely used in a particular at a particular time than other alternatives. Accordingly, it is recommended that an expanded literature review be conducted to here, that considers these questions for the Flattop chalcedony and the other lithic sources used by groups in Central Plains, identified by Holen (2014), to determine the extent of the terrane of Flattop chalcedony at different times in the ancient past.

Record Collections from Flattop Butte in Private Collections

Flattop Butte has been well known to collectors in northeastern Colorado for many decades. As a result many artifacts from Flattop Butte are present in local, privately owned collections. In at least one case, location information has been recorded (in some cases general areas, in other cases GPS coordinates) regarding the location on the butte where artifacts were discovered (Mike Toft, personal communication 2023). It is recommended that these private collections of materials from the surface of Flattop Butte be recorded by photographing these artifacts and, where available recording the location where they were found.

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APPENDIX A:
HISTORY OF SMITHSONIAN INSTITUTION TRINOMIAL SYSTEM (SITS) IDENTIFIERS USED TO DESCRIBE FLATTOP BUTTE

Flattop Butte has been assigned the unique identifier "5LO34" in the Smithsonian Institution Trinomial System (SITS) although, as discussed in more detail below, it has been referred to using other SITS identifiers over the last 75 years. The SITS system was developed in the 1940s for identifying archaeological sites in connection with Smithsonian's then-ongoing River Basin Survey project in the northern Great Plains, and was later extended for use in identifying sites throughout the United States (Digtech 2012). The SITS system assigns a three-part unique identifier to each site consisting (in order) of: (i) a one- or two-digit code for the state, (ii) a two-letter code for the county (or equivalent) within the state, and (iii) one or more digits assigned to the specific site, based on the order it was listed in the county. So for example, Flattop Butte's designation as 5LO34, indicates that it is located in the State of Colorado (state number 5 in the SITS system), in Logan County (designated "LO"), and is the 34th site to be assigned a SITS identifier in the county. The Smithsonian Institution stopped maintaining the SITS system in 1967, and since that time unique identifiers have been assigned by state historic preservation offices (SHPOs) (Digtech 2012).

Flattop Butte was assigned the unique identifier 5LO34 in 1981 by the Colorado Historical Society (now known as History Colorado) based on a report, by former Logan County resident Milton Wilbur, of an "Indian village" located on the butte (History Colorado 2006). Together with its SITS identifier, the site was given two names, "Flattop Quarry" and "Flattop Butte Rings" (History Colorado 2006). Since 1981 (with one exception, discussed below), Flattop Butte has consistently been referred to in the archaeological literature by the SITS identifier 5LO34 (e.g. Greiser 1983).

However, at some unknown date after the site was recorded as 5LO34, Flattop Butte was assigned a different SITS identifier, "5LO473," by the Colorado Historical based on a 1949 recording of the site by E. Mott Davis from information provided by an informant, Richard Rinker of Hamilton, Kansas (History Colorado 1949). This 1949 report makes no mention of the name "Flattop," but instead names the site "Baby Rattlesnake Site," no doubt based on Davis' warning that the site is "infested with rattlesnakes. They hibernate here and females have litters here." (History Colorado 1949:1). Other than in the 1949 site report filed by Davis, the SITS identifier 5LO473 has not been used elsewhere to refer to Flattop Butte.

In 1972, a third SITS identifier, "5LG121," appears in the Colorado State University archaeological site card catalog system referring to Flattop Butte. This "LG" based identifier was used by Dr. Elizabeth Morris, professor of archaeology at CSU, for numbering sites from the 1972 field school in Logan County, Colorado, mostly in and around the Dipper Gap site. The letters "LG" are not the official SITS abbreviation for Logan County, and no site in Logan county is identified with the digits "121" in the Colorado SHPO site files. Outside of the CSU card catalog system, the identifier 5LG121 has not been used to refer Flattop Butte.

A fourth SITS identifier, "5LO1," was erroneously used in two instances, first in 1977 by Stanley Ahler to identify Flattop Butte in a publication relating to the use of WRGS materials in the Middle Missouri subarea of North Dakota (Ahler 1977:234); and then in again in 1984 by David Ives (citing Ahler 1977) in his PhD dissertation on neutron activation analysis of prehistoric chert sources (Ives 1984:56). This identifier was never assigned by the Colorado SHPO to Flattop Butte. Rather, 5LO1 was assigned to the Peavey Rockshelter site, eleven miles west of Flattop Butte, in 1969 (History Colorado 1969). In 1985, Nowak and Hannus referred to Flattop Butte as both 5LO1 and 5LO34 in a discussion of lithic sources in the region (1985:110). Since then, Flattop Butte has not been referred to using the erroneous 5LO1 identifier.

A fifth and final SITS identifier, "5LO12," appears in the University of Denver's "Past Perfect" record system to refer to Flattop Butte, and the associated records of E. B. Renaud's visit to the site in 1930 (Sarah Carlson, personal communication 2023). It is not clear where this identifier originated, as it has never been associated with Flattop Butte, or any other site, by the Colorado Historical Society.

As discussed in Chapter Two, before the SITS system was initiated in the 1940's, Flattop Butte was identified by E. B. Renaud of the University of Denver as R34 in his published report on the archaeology of eastern Colorado (1932:24). However, in his field notes, Renaud refers to Flattop Butte as R-35, both when describing it as well as on a hand-drawn map of the area (1930:29a, 31). Adding to the confusion, later in his published report, Renaud refers again to R34, but this time not in reference to Flattop Butte, but rather in reference to a site to the north, in Chimney Cañon (1932:25), which appears to be the site Renaud originally designated R-34 in his field notes (1930:29a, 31).

APPENDIX B: DESCRIPTIONS, PREVALENCE, AND SPATIAL DISTRIBUTION OF FLATTOP CHALCEDONY COLOR VARIETIES

Descriptions

As previously noted, the color varieties of Flattop chalcedony are sorted here into four general groups: purple, red, brown, and white. While the color of individual specimen can be described with more particularity, the variation within these colors varieties is sufficiently pronounced as to make further generalizations of limited use, at least for the purposes of this investigation. This is well illustrated by the attempts of six previous investigators to describe the colors of Flattop chalcedony using the Munsell Soil Color Charts as shown in Table 6 (Carlson and Peacock 1974; Greiser 1983; Nowak and Hannus (1985); Jensen 1973; Hoard et al. 1992).[38]

Table 6. Prior descriptions of Flattop chalcedony colors.

Report	***Color Names***	***Munsell Notations***
Jensen (1973)	gray, grayish brown, pinkish gray, reddish gray	10YR hue, 5-6 value, 1-2 chroma 5YR hue, 4-6 value, 1-3 chroma
Carlson and Peacock (1974)	white, light gray, reddish gray, pale red, weak red	10R hue, 4-6 value, 1-3 chroma 10YR hue, 7-8 value, 1 chroma
Greiser (1983)	white, pink, lavender, blue	10R hue, 4-6 value, 1-3 chroma 10YR hue, 7-8 value, 1 chroma
Nowak and Hannus (1985)	reddish gray, weak red, dark reddish gray	10R hue, 4-6 value, 1-4 chroma
Hoard et al. (1992)	white, gray, brown, lavender, reddish purple	10R hue, 3-6 value, 1-3 chroma 10YR hue, 5 value, 1 chroma 5YR hue, 6 value, 1 chroma 5Y hue, 8 value, 2 chroma

As set forth in Table 6, these researchers assigned a variety of color names and Munsell notations, with strikingly limited overlap, to describe the color varieties of Flattop chalcedony appearing at the site. For example, fourteen color names are used in these five reports, but none of

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[38] Ahler also provides Munsell descriptions of the color varieties of a material he refers to as "Flattop Chalcedony." (1977:134-135). However, he uses this designation to refer not only to material from Flattop Butte, but also other WRGS materials outcropping in western Nebraska, and southwestern South Dakota. Accordingly, Ahler's descriptions are not included in Table 6.

them is used in all of the reports, and eight of them are used in only one report. The most common names, white and reddish gray, appear in only three of the five reports. As for Munsell notations, four different hues are reported, but none appears in all reports. The most common hues,10R and 10YR, appear in four of the five reports, followed by 5 YR which appears in two reports. 5Y appears in only one report. Within these hues, the values and chroma reported show similar, though less pronounced, differences.

Prevalence and Spatial Distribution

As part of the survey undertaken in connection with the present investigation, data were gathered regarding the prevalence and relative distribution of the four different color varieties of Flattop chalcedony (purple, red, brown, and white) appearing at 78 high-density debris locations at different locations across the butte. Specifically, for each of the high-density debris areas examined, surveyors measured and recorded the volume and relative frequency of each of the color varieties appearing on the surface. The results are set forth in Appendix K and are discussed hereafter.

Prevalence

As summarized in Table 7 below, these results show that purple is the most common color variety of Flattop chalcedony appearing in the 78 high-density debris areas analyzed. It makes up nearly 37% of the total volume of material appearing on the surface of these locations. It is also the most prevalent (or tied for the most prevalent) color type in more than half (51.2%) of the 78 high-density debris areas analyzed. The next most common color type is white, making up just over 25% of the total sample, and being the most prevalent in 38.5% of the high-density debris areas. Thereafter, the third most common color type is brown, making up nearly 22% of the sample, and being the most prevalent in 25.6% of the areas sampled. Finally, the least common color type is red, making up only 15.9% of the total sample, and being the most prevalent in only 9% of the areas sampled.

Table 7. Prevalence of color-varieties of Flattop chalcedony in tested high-density debris areas.

Color	**Total Volume (cm^3)**	**% of Total Volume**	**Most Prevalent Color in Unit**
Purple	18,183	36.9%	40 (51.2%)
Red	7,827	15.9%	7 (9%)
Brown	10,734	21.8%	20 (25.6%)
White	12,506	25.4%	30 (38.5%)

On this question of prevalence of colors within individual high-density debris areas, it is worth noting the white color type of Flattop chalcedony appears to be more dominant in low density areas, being the most prevalent color type in 65% of the 20 lowest density debris areas analyzed, as compared with being the most prevalent in only 25% of the 20 highest density debris areas (Appendix K). Conversely, the purple variety of Flattop chalcedony appears to be more dominant in high-density areas, being the most prevalent color type in 70% of the 20 highest density debris areas, as compared with only 20% of the 20 lowest density debris areas (Appendix K).

Spatial Distribution

The analysis of the distribution of color varieties of Flattop chalcedony in the 78 high-density debris areas discussed above also produced data about the volume and spatial distribution of these varieties, as well as their associations with each other (Appendix K). As summarized in Table 8 below, these data show that the purple, brown, and white color varieties appear together in almost all surveyed locations across the butte, with purple appearing in nearly 94% of the tested locations, brown appearing in nearly 95%, and white appearing in more than 96% (Appendix K). In contrast, the red color variety is less ubiquitous, being entirely absent from nearly a third of the surveyed high-density debris areas (Appendix K, Table 8).

Table 8. Distributions of color-varieties of Flattop chalcedony in tested high-density debris areas

Color	Number of Units with Color Variety	Percentage of Units with Color Type
Purple	73 of 78	93.6%
Red	54 of 78	69.2%
Brown	74 of 78	94.9%
White	75 of 78	96.2%

These results indicate that the purple, brown, and white varieties of Flattop chalcedony usually formed, and are bedded, together in the limestone caprock as distinct but associated packets of cryptocrystalline silicate, such that when ancient groups extracted and reduced these packets they left behind debris areas in which these three color varieties typically appear together (over 88% of the time) (Appendix K). As for the red variety, the data suggest that in most cases it too formed, and is now bedded, with the purple, brown, and white varieties, although significant, localized exceptions exist. This explanation is consistent with Ahler's (1977) general description of WRGS outcropping in western Nebraska, eastern Colorado, and southwestern South Dakota, as consisting of purple, red, and brown chalcedonies, and opaque white chert, "mingled or irregularly bedded" together (1977:134).

The data gathered here regarding the distribution of color types of Flattop chalcedony in high-density debris areas also yield information regarding the relative density of debris of different color types across the surface of the butte (Appendix K). This data is graphically displayed below in Figure 75, which uses inverse distance weighting to estimate the volume of unmeasured areas based on the average volume of nearby measured areas, with closer areas having a greater influence on the estimate.

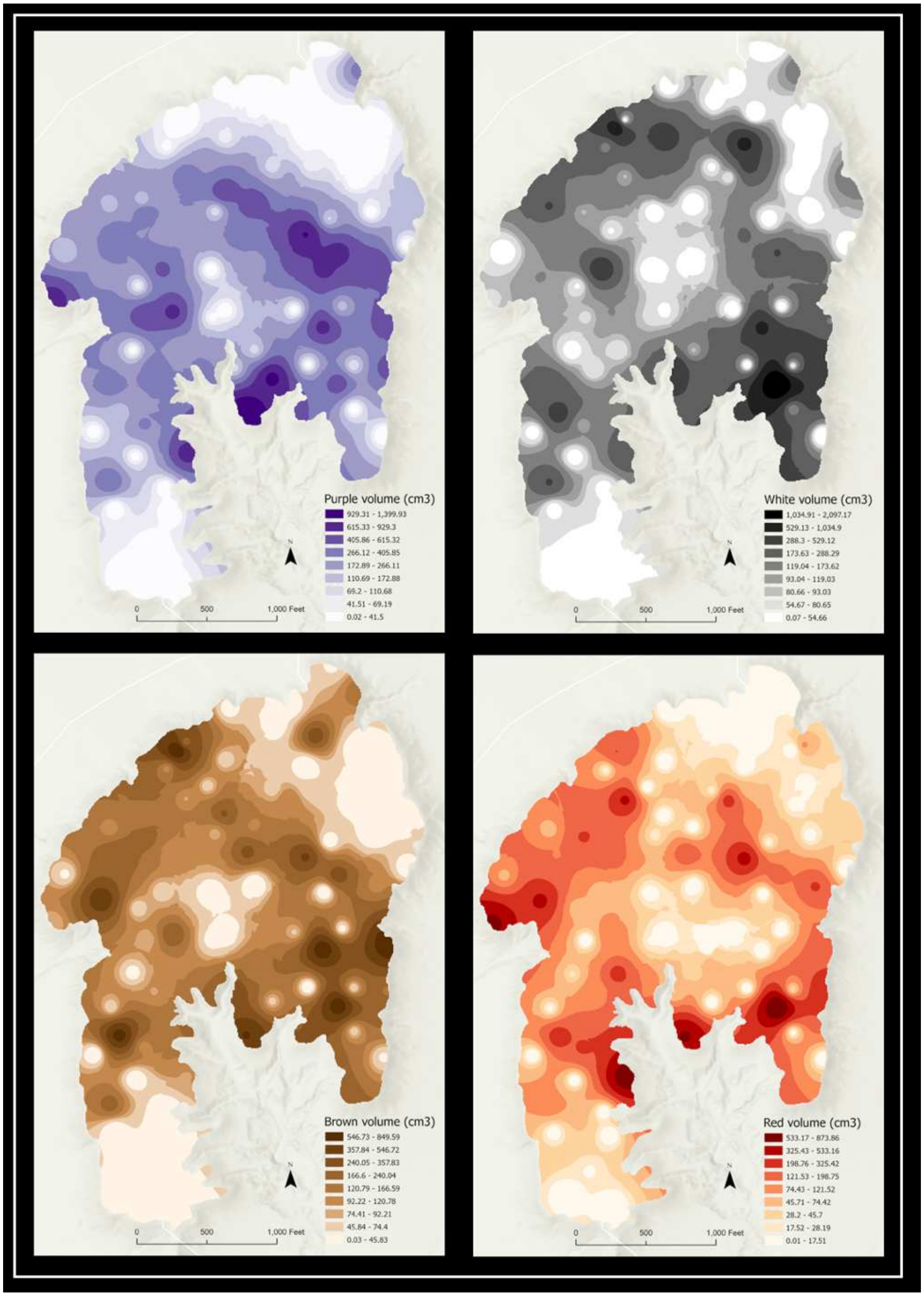

Figure 75. Maps of spatial distribution of color varieties of Flattop chalcedony, based on volumes in tested high-density debris areas, extrapolated using inverse distant weighting. Created by Joshua Reyling, Geospatial Centroid, Colorado State University.

As can be seen in Figure 75, all of the color varieties appear at most locations across the Central portion of the Flattop Butte described as the lithic reduction zone in Chapter Six. This pattern is most prominent with the purple variety, which is mostly absent from the north and south portions of the butte. The brown and white varieties are the most common in the north portion of the butte, but also mostly absent to the south. The red variety is the most common in the south, although it does not extend to the terminus of the butte and is mostly absent from the north portion.

APPENDIX C:
OTHER WHITE RIVER GROUP SILICATES

In addition to Flattop chalcedony, the other named varieties of the White River Group silicates are West Horse chert, Scenic chalcedony, Table Mountain chert, and Sentinel Butte chert (Figure 10). Each is discussed in turn below, followed by a discussion of methods for distinguishing between the varieties.

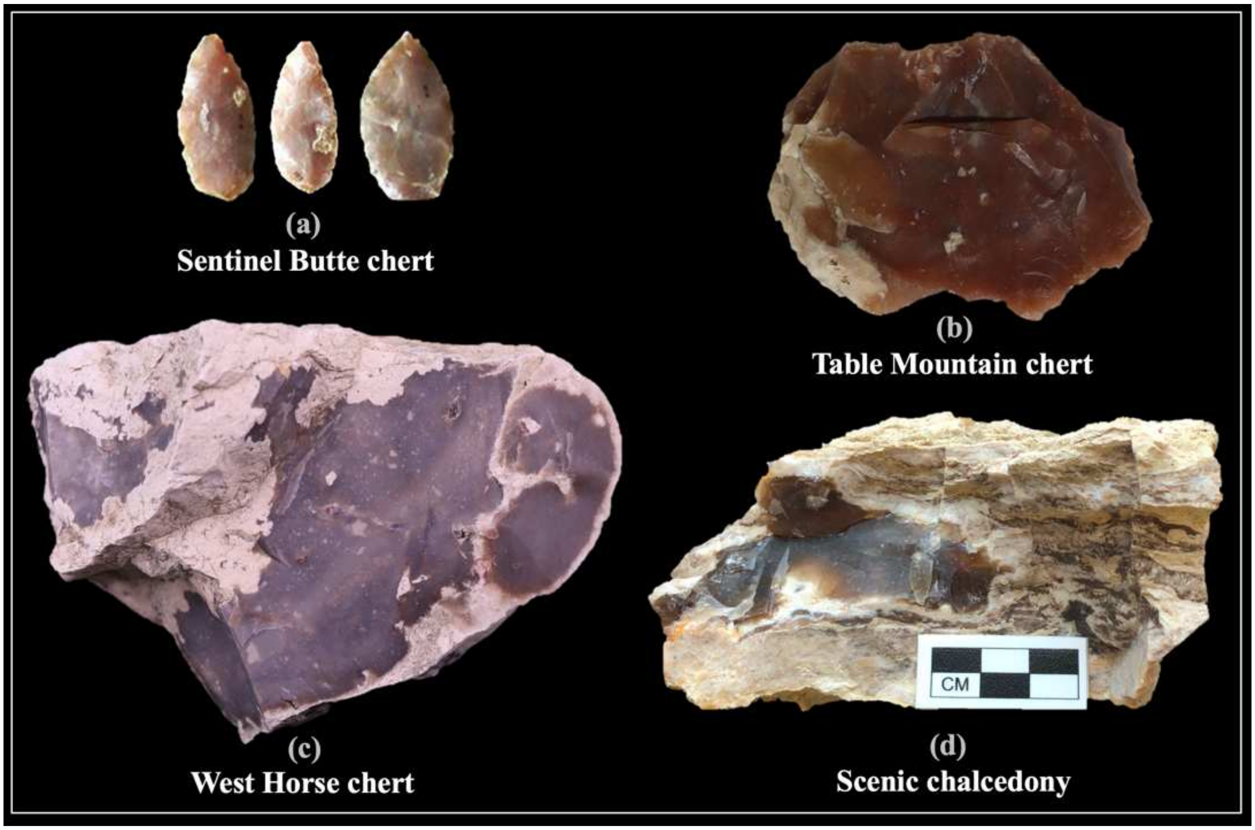

Figure 10. Other named varieties of White River Group Silicates (WRGS).
From: Boen et al. (2021); Huckell et al. (2011); Mike Toft collection; (c) CMPA lithics collection.

West Horse Chert

West Horse chert appears together with Scenic chalcedony at two locations in the White River badlands of southwestern South Dakota: the West Horse Creek quarry (39SH37) and the Nelson Butte quarry (39SH78) (Hoard et al. 1993; Lueck and Butterbrodt 1984; Nowak and

Hannus 1985). The color of West Horse chert has been described as “a very distinct purplish-gray” (Nowak and Hannus 1985:109), with Munsell notations including hues of 5YR, 7.5YR, and 10YR, values from 3-7, and chroma from 0-1 (light gray, dark gray, very dark gray), as well as hues of 10R, a value of 3, and chroma of 1 (dark reddish gray) (Hoard et al. 1993; Nowak and Hannus 1985). West Horse chert displays occasional banding, gray lenses, or a reddish tint or vein, and a cortex of white to gray hard limestone. (Hoard et al. 1993; Nowak and Hannus 1985).

At West Horse Creek quarry, West Horse chert outcrops in exposed foliated limestone at a crossing of West Horse Creek (Figure 76), in three separate exposures (Hoard et al. 1993; Nowak and Hannus 1985). These exposures are surrounded by 1680 acres of continuous lithic debris scatter and at least 14 discernable concentrations of artifacts and workshop debris (Nowak and Hannus 1985). The tool stone deposits at the quarry consist of two distinct layers, a 15-40 cm lower layer of purple-gray West Horse chert and a 2-10 cm upper layer of dark brown Scenic chalcedony (Hoard et al. 1993; Nowak and Hannus 1985).

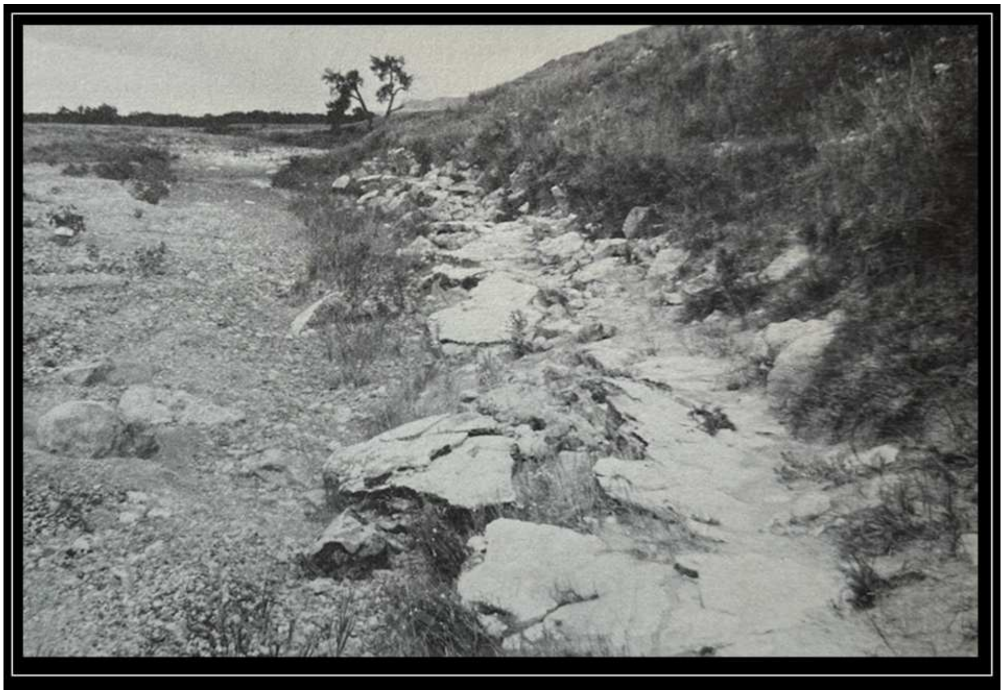

Figure 76. Limestone outcrop with exposures of West Horse Chert and Scenic Chalcedony. From Nowak and Hannus 1985:Figure 4.

The other source of West Horse chert is from the Nelson Butte quarry in the Battle Creek Canyon area of the White River Badlands in southwestern South Dakota, where lithic materials were extracted from locations along the top and along the steep slopes of the butte, including a large depression on the northeast face of the butte where ancient quarriers undercut and exposed chert-bearing deposits (Hoard et al. 1993; Lueck and Butterbrodt 1984:27; Nowak and Hannus 1985). The Nelson Butte quarry, like the West Horse Creek quarry, also produces Scenic chalcedony. (Hoard et al. 1993). The West Horse chert from the Nelson Butte quarry is described as having a less reddish tint than its West Horse Creek counterpart, with Munsell notations ranging from a hue of 5YR, a value of 5, and a chroma of 1 (gray) to a hue of 10YR, value of 7, and a chroma of 2 (light gray) (Nowak and Hannus 1985). The West Horse chert from the Nelson Butte quarry is said to be "very similar" to the more purple-gray varieties of Flattop chalcedony (Nowak and Hannus 1985:110).

Scenic Chalcedony

As noted above, Scenic chalcedony appears in the same quarry locations as West Horse chert, at the Nelson Butte and West Horse Creek quarries in the White River badlands of the southwestern South Dakota. In both locations, it appears in layers above the West Horse chert (Nowak and Hannus 1985).

The color of Scenic chalcedony has been described as a "translucent dark brown" (Nowak and Hannus 1985) or "fine dark brown" (Hoard et al. 1993), with Munsell color notations of 5YR hue, 2.5-3 value, and 2-3 chroma (dark reddish-brown); and 10YR hue, 3-5 value, and 2-4 chroma (reddish gray, dark yellowish brown, very dark grayish brown) (Hoard et al. 1993; Nowak et al. 1985). Scenic chalcedony is very similar to, and can easily be mistaken for, Knife River flint from southwestern North Dakota (Nowak and Hannus 1985). Scenic chalcedony from the Nelson Butte quarry is also similar to a pinkish-gray to dark brown variety of Flattop chalcedony, although the Flattop material is said to be distinguishable based on the presence of reddish lenses or occlusions (Nowak and Hannus 1985).

Table Mountain Chert

Table Mountain chert has its source at the Table Mountain quarry (48G0248), an isolated butte covering approximately 6 km^2 in the North Platte River basin of esastern Wyoming, near the Nebraska boarder (Hoard et al. 1993). The most common color of Table Mountain chert has been described as pink, dark reddish gray, grayish red, and pale red, with white, gray, purple, and yellow material also present but less common (Hoard et al. 1993; Koch and Miller 1996:107). Munsell color notations include: hue 10R, values 3-6, chroma 1-3 (weak red, pale red, reddish gray, dark reddish gray); 5R hue, 4-6 value, chroma 2 (pale red); 5YR hue, 4 value, and 3 chroma (reddish brown); 2.5YR hue, value 3-4, chroma 2 (weak red, dusky red); 2.5Y hue, value 6-7, chroma 3 (pale yellow, light yellowish brown); 10R hue, value 4, chroma 2 (weak red); 10YR hue, 4 value, and 2 chroma (dark yellowish gray); and 10YR hue, values 7-8, chroma 1-2 (light gray, white). Table Mountain chert displays frequent banding, occasional inclusions of white or purple, a smooth and waxy texture, and a cortex of gray or white limestone (Hoard et al. 1993; Koch and Miller 1996:107).

Table Mountain chert appears in abundance on the top of Table Mountain Butte and down all of its talus slopes, with spoil piles and quarry pits evident in unplowed tracts near the butte's edge. (Hoard et al. 1993; Koch and Miller 1996:106). The material is bedded within three major horizons where it occurs in 5-20 cm beds contained in limestones and marlstones associated with shallow stratified or ephemeral playa lake deposits (Koch and Miller 1996:106). The upper horizon, occurring at elevations from 1310-1370 m above mean sea level (AMSL), forms the caprock of the butte and is covered by approximately two meters of topsoil (Hoard et al. 1993; Koch and Miller 1996:106-107). The middle horizon is exposed around the middle of the slope, around 1292 m AMSL, and forms a distinctive bench (Koch and Miller 1996:106). The lower horizon, from 1258-1256 m AMSL, has broad exposures extending from the base of the butte (Koch and Miller 1996:107). The highest quality Table Mountain chert comes from the upper horizon, with poorer quality material being more common in the middle and lower horizon (Koch and Miller 1996:107).

Sentinel Butte Chert

Sentinel Butte chert has its source in one of the most prominent landmarks in southwestern North Dakota, Sentinel Butte (32GV97), the surface of which covers approximately 225 acres at a height of over 1030 meters, rising above the surrounding landscape of valleys, ridges, and hills (Huckell et al. 2011). Sentinel Butte chert appears primarily in the form of rounded irregular nodules, most being from 5-10 cm in maximum dimension (Huckell et al 2011).

The color of fresh faces on nodules of Sentinel Butte chert has been described (using the GSA Rock-Color Chart, 1995) as ranging from medium dark gray (N4) to medium light gray (N7) with N5e and N6 being the most common colors (Huckell et al 2011). Flakes struck from these nodules display a range of colors with the most common being light brownish gray (5 YR 6/1) and medium light gray (N6) (Huckell et al. 2011). Under short wave UV light, flakes of Sentinel Butte chert fluoresce a pale lime green, with a splotchy green appearing under long wave UV light (Huckell et al. 2011).

Sentinel Butte chert is translucent, with a dull luster and a texture that ranges from very fine- to medium-grained (Huckell et al. 2011). When it is present, cortex is chalky and varies from <1 mm to a 1-3 mm, with thick calcium carbonate coatings frequently appearing on recently exposed nodules (Huckell et al. 2011).

Distinguishing the Varieties of WRGS

Numerous attempts have been made at distinguishing the different varieties of WRGS, and associating them with their source locations, with varying results. One of the earliest attempts was by Ahler (1977), who identified three distinctive raw material types outcropping in the White River Group. He designated these: (i) "Chadron Chert," outcropping in southwestern and south-central South Dakota, (ii) "Plate Chalcedony," outcropping in northwestern Nebraska and southwestern South Dakota, and (iii) "Flattop Chalcedony," which was not limited to material originating at the Flattop Butte quarry site, but rather included similar WRGS materials outcropping over a wide area in eastern Colorado, western Nebraska, and southwestern South Dakota (Ahler 1977:134-136). Ahler distinguished these materials based on visual characteristics such as microcrystalline structure, color, luster, relative translucence/opacity, and forms of cortex (1977). After Ahler, for at least a time, visual characteristics were generally considered sufficient to distinguish the varieties of WRGS, as evidenced by Greiser's observation that "although an occasional piece [of WRGS] may be confused from one outcrop to the next, these materials are generally distinguishable on the basis of color" (1983:6-7).

This view was rejected, however, by Hoard et al. (1993) who asserted that specimens of WRGS from different sources "are often visually indistinguishable," meaning that "visual inspection of WRGS is insufficient for determining its source" (1993:698-699, 708). Instead, these authors argued for the use of neutron-activation analysis (NAA) to differentiate WRGS varieties based on their elemental composition (Hoard et al. 1993). Specifically, they analyzed WRGS source specimens from Flattop Butte in Colorado, Table Mountain in Wyoming, and the West Horse Creek and Nelson Butte sources in South Dakota (both being treated as a single analytic unit) (Hoard et al. 1993). Based on this analysis, they concluded that WRGS materials from these sources can be differentiated from each other using NAA (Hoard et al. 1993).[39]

Similarly, Huckell et al. (2010) used NAA to analyze samples of Sentinel Butte chert from its source location in North Dakota and compared those results to previously obtained NAA results obtained by Hoard et al. (1992, 1993) for materials sourced from Flattop Butte, Table Mountain, West Horse Creek, and Nelson Butte. Based on this analysis, they concluded that material from the Sentinel Butte source can be differentiated from the other WRGS sources based on its elemental composition (Huckell et al. (2010).

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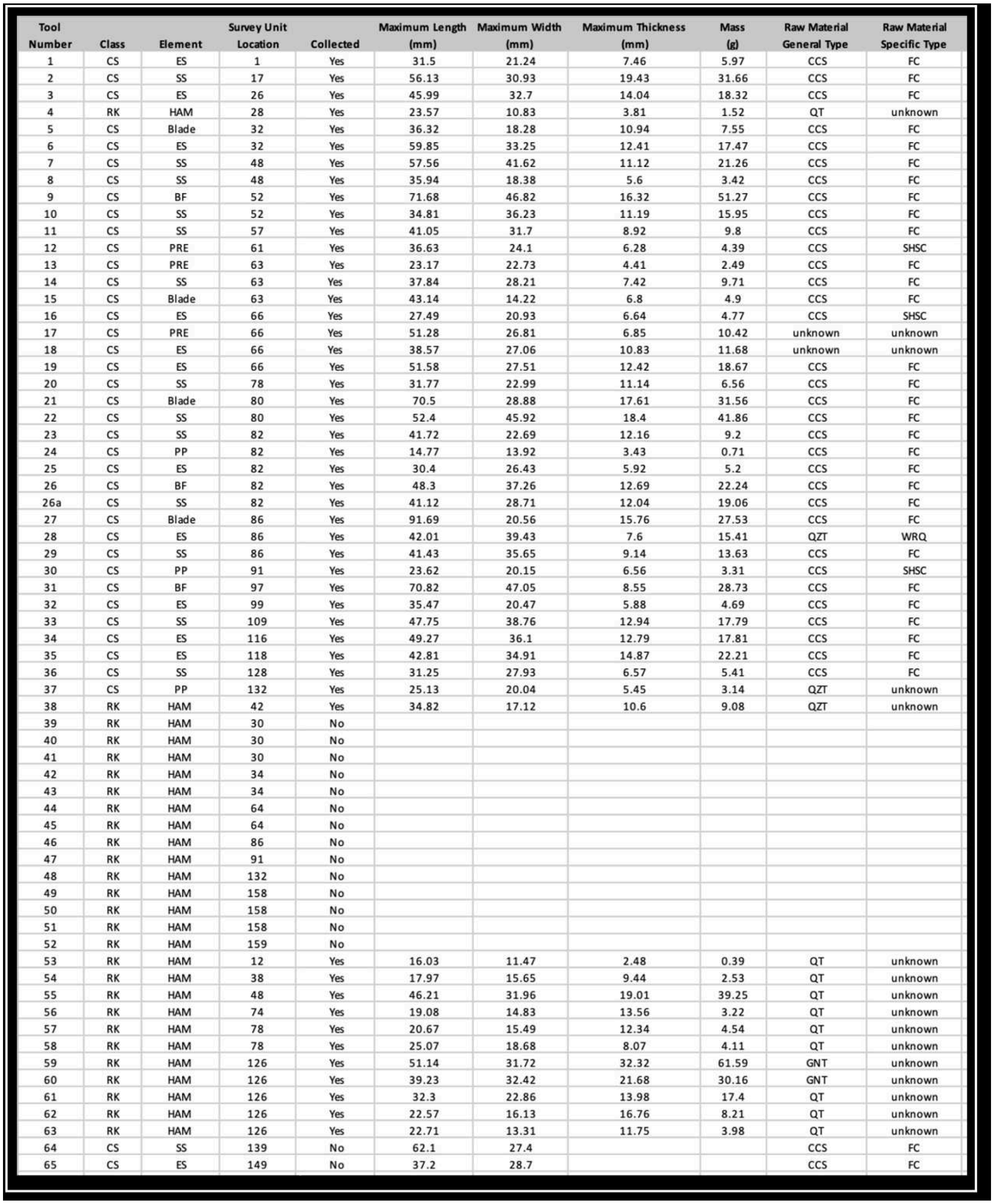
[39] Previously, Ives (1984) had used NAA to study and distinguish various sources of cryptocrystalline silicates in the Great Plains, including Flattop Butte. While Ives produced valuable elemental signatures for Flattop chalcedony, he did not compare them to other WRGS sources.

APPENDIX D:
FINISHED TOOLS AND HAMMERSTONES DATA

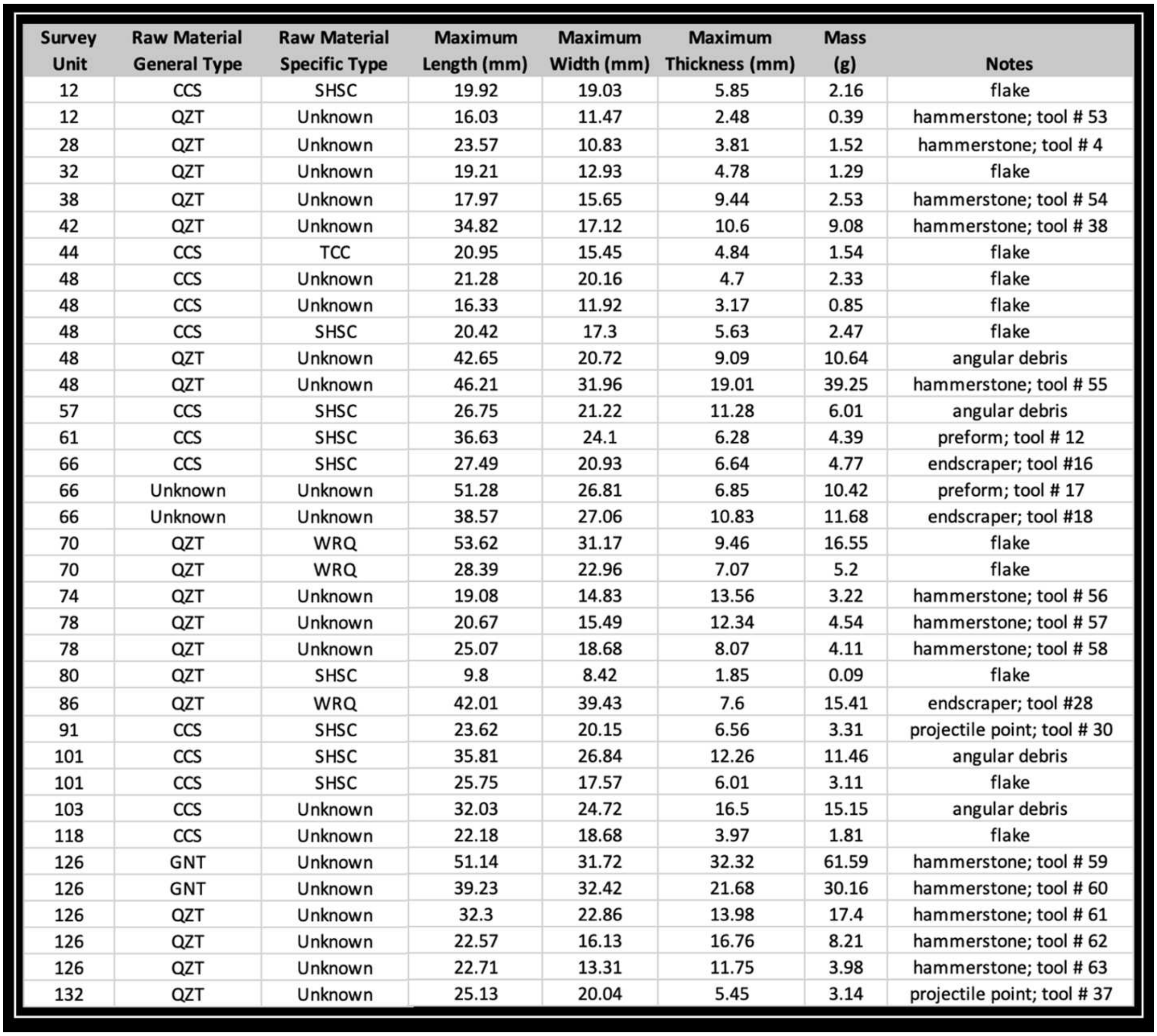


Tool Number	Class	Element	Survey Unit Location	Collected	Maximum Length (mm)	Maximum Width (mm)	Maximum Thickness (mm)	Mass (g)	Raw Material General Type	Raw Material Specific Type
1	CS	ES	1	Yes	31.5	21.24	7.46	5.97	CCS	FC
2	CS	SS	17	Yes	56.13	30.93	19.43	31.66	CCS	FC
3	CS	ES	26	Yes	45.99	32.7	14.04	18.32	CCS	FC
4	RK	HAM	28	Yes	23.57	10.83	3.81	1.52	QT	unknown
5	CS	Blade	32	Yes	36.32	18.28	10.94	7.55	CCS	FC
6	CS	ES	32	Yes	59.85	33.25	12.41	17.47	CCS	FC
7	CS	SS	48	Yes	57.56	41.62	11.12	21.26	CCS	FC
8	CS	SS	48	Yes	35.94	18.38	5.6	3.42	CCS	FC
9	CS	BF	52	Yes	71.68	46.82	16.32	51.27	CCS	FC
10	CS	SS	52	Yes	34.81	36.23	11.19	15.95	CCS	FC
11	CS	SS	57	Yes	41.05	31.7	8.92	9.8	CCS	FC
12	CS	PRE	61	Yes	36.63	24.1	6.28	4.39	CCS	SHSC
13	CS	PRE	63	Yes	23.17	22.73	4.41	2.49	CCS	FC
14	CS	SS	63	Yes	37.84	28.21	7.42	9.71	CCS	FC
15	CS	Blade	63	Yes	43.14	14.22	6.8	4.9	CCS	FC
16	CS	ES	66	Yes	27.49	20.93	6.64	4.77	CCS	SHSC
17	CS	PRE	66	Yes	51.28	26.81	6.85	10.42	unknown	unknown
18	CS	ES	66	Yes	38.57	27.06	10.83	11.68	unknown	unknown
19	CS	ES	66	Yes	51.58	27.51	12.42	18.67	CCS	FC
20	CS	SS	78	Yes	31.77	22.99	11.14	6.56	CCS	FC
21	CS	Blade	80	Yes	70.5	28.88	17.61	31.56	CCS	FC
22	CS	SS	80	Yes	52.4	45.92	18.4	41.86	CCS	FC
23	CS	SS	82	Yes	41.72	22.69	12.16	9.2	CCS	FC
24	CS	PP	82	Yes	14.77	13.92	3.43	0.71	CCS	FC
25	CS	ES	82	Yes	30.4	26.43	5.92	5.2	CCS	FC
26	CS	BF	82	Yes	48.3	37.26	12.69	22.24	CCS	FC
26a	CS	SS	82	Yes	41.12	28.71	12.04	19.06	CCS	FC
27	CS	Blade	86	Yes	91.69	20.56	15.76	27.53	CCS	FC
28	CS	ES	86	Yes	42.01	39.43	7.6	15.41	QZT	WRQ
29	CS	SS	86	Yes	41.43	35.65	9.14	13.63	CCS	FC
30	CS	PP	91	Yes	23.62	20.15	6.56	3.31	CCS	SHSC
31	CS	BF	97	Yes	70.82	47.05	8.55	28.73	CCS	FC
32	CS	ES	99	Yes	35.47	20.47	5.88	4.69	CCS	FC
33	CS	SS	109	Yes	47.75	38.76	12.94	17.79	CCS	FC
34	CS	ES	116	Yes	49.27	36.1	12.79	17.81	CCS	FC
35	CS	ES	118	Yes	42.81	34.91	14.87	22.21	CCS	FC
36	CS	SS	128	Yes	31.25	27.93	6.57	5.41	CCS	FC
37	CS	PP	132	Yes	25.13	20.04	5.45	3.14	QZT	unknown
38	RK	HAM	42	Yes	34.82	17.12	10.6	9.08	QZT	unknown
39	RK	HAM	30	No						
40	RK	HAM	30	No						
41	RK	HAM	30	No						
42	RK	HAM	34	No						
43	RK	HAM	34	No						
44	RK	HAM	64	No						
45	RK	HAM	64	No						
46	RK	HAM	86	No						
47	RK	HAM	91	No						
48	RK	HAM	132	No						
49	RK	HAM	158	No						
50	RK	HAM	158	No						
51	RK	HAM	158	No						
52	RK	HAM	159	No						
53	RK	HAM	12	Yes	16.03	11.47	2.48	0.39	QT	unknown
54	RK	HAM	38	Yes	17.97	15.65	9.44	2.53	QT	unknown
55	RK	HAM	48	Yes	46.21	31.96	19.01	39.25	QT	unknown
56	RK	HAM	74	Yes	19.08	14.83	13.56	3.22	QT	unknown
57	RK	HAM	78	Yes	20.67	15.49	12.34	4.54	QT	unknown
58	RK	HAM	78	Yes	25.07	18.68	8.07	4.11	QT	unknown
59	RK	HAM	126	Yes	51.14	31.72	32.32	61.59	GNT	unknown
60	RK	HAM	126	Yes	39.23	32.42	21.68	30.16	GNT	unknown
61	RK	HAM	126	Yes	32.3	22.86	13.98	17.4	QT	unknown
62	RK	HAM	126	Yes	22.57	16.13	16.76	8.21	QT	unknown
63	RK	HAM	126	Yes	22.71	13.31	11.75	3.98	QT	unknown
64	CS	SS	139	No	62.1	27.4			CCS	FC
65	CS	ES	149	No	37.2	28.7			CCS	FC

ABBREVIATIONS KEY

Class (CS = chipped stone; RK = rock). **Element** (BF = biface; ES = end scraper; HAM = hammerstone; PP = projectile point; PRE = preform; SS = side scraper). **Raw Material**: (CCS = cryptocrystalline silicate; GNY = granite; QT = quartz; QZT = quartzite). **Lithic Source**: FC = Flattop chalcedony; SHSC = Smoky Hill silicified chalk; WRQ = Windy Ridge quartzite.

APPENDIX E:
EXOTIC MATERIALS (NON-FLATTOP CHALCEDONY) DATA



Survey Unit	Raw Material General Type	Raw Material Specific Type	Maximum Length (mm)	Maximum Width (mm)	Maximum Thickness (mm)	Mass (g)	Notes
12	CCS	SHSC	19.92	19.03	5.85	2.16	flake
12	QZT	Unknown	16.03	11.47	2.48	0.39	hammerstone; tool # 53
28	QZT	Unknown	23.57	10.83	3.81	1.52	hammerstone; tool # 4
32	QZT	Unknown	19.21	12.93	4.78	1.29	flake
38	QZT	Unknown	17.97	15.65	9.44	2.53	hammerstone; tool # 54
42	QZT	Unknown	34.82	17.12	10.6	9.08	hammerstone; tool # 38
44	CCS	TCC	20.95	15.45	4.84	1.54	flake
48	CCS	Unknown	21.28	20.16	4.7	2.33	flake
48	CCS	Unknown	16.33	11.92	3.17	0.85	flake
48	CCS	SHSC	20.42	17.3	5.63	2.47	flake
48	QZT	Unknown	42.65	20.72	9.09	10.64	angular debris
48	QZT	Unknown	46.21	31.96	19.01	39.25	hammerstone; tool # 55
57	CCS	SHSC	26.75	21.22	11.28	6.01	angular debris
61	CCS	SHSC	36.63	24.1	6.28	4.39	preform; tool # 12
66	CCS	SHSC	27.49	20.93	6.64	4.77	endscraper; tool #16
66	Unknown	Unknown	51.28	26.81	6.85	10.42	preform; tool # 17
66	Unknown	Unknown	38.57	27.06	10.83	11.68	endscraper; tool #18
70	QZT	WRQ	53.62	31.17	9.46	16.55	flake
70	QZT	WRQ	28.39	22.96	7.07	5.2	flake
74	QZT	Unknown	19.08	14.83	13.56	3.22	hammerstone; tool # 56
78	QZT	Unknown	20.67	15.49	12.34	4.54	hammerstone; tool # 57
78	QZT	Unknown	25.07	18.68	8.07	4.11	hammerstone; tool # 58
80	QZT	SHSC	9.8	8.42	1.85	0.09	flake
86	QZT	WRQ	42.01	39.43	7.6	15.41	endscraper; tool #28
91	CCS	SHSC	23.62	20.15	6.56	3.31	projectile point; tool # 30
101	CCS	SHSC	35.81	26.84	12.26	11.46	angular debris
101	CCS	SHSC	25.75	17.57	6.01	3.11	flake
103	CCS	Unknown	32.03	24.72	16.5	15.15	angular debris
118	CCS	Unknown	22.18	18.68	3.97	1.81	flake
126	GNT	Unknown	51.14	31.72	32.32	61.59	hammerstone; tool # 59
126	GNT	Unknown	39.23	32.42	21.68	30.16	hammerstone; tool # 60
126	QZT	Unknown	32.3	22.86	13.98	17.4	hammerstone; tool # 61
126	QZT	Unknown	22.57	16.13	16.76	8.21	hammerstone; tool # 62
126	QZT	Unknown	22.71	13.31	11.75	3.98	hammerstone; tool # 63
132	QZT	Unknown	25.13	20.04	5.45	3.14	projectile point; tool # 37

ABBREVIATIONS KEY

Raw Material: (CCS = cryptocrystalline silicate; GNY = granite; QZT = quartzite).

Lithic Source: SHSC = Smoky Hill silicified chalk; WRQ = Windy Ridge quartzite.

APPENDIX F:
RADIOCARBON ANALYSIS REPORTS

1785
The University of Georgia
Center for Applied Isotope Studies

RADIOCARBON ANALYSIS REPORT

October 12, 2023

Robert Madden
Colorado State University
1360 Walnut Street, Unit 201
Boulder, CO 80302

Dear Dr. Madden,

Enclosed please find the results of ^{14}C Radiocarbon analyses and Stable Isotope Ratio δ^{13}C analyses for the samples received by our laboratory on September 18, 2023.

UGAMS#	Sample ID	Material	δ^{13}C,‰	δ^{15}N,‰	C/N	^{14}C age, years BP	±	pMC	±
66155	1	collagen	-9.63	9.57	3.22	620	20	92.6	0.27
66156	2	collagen	-18.71	5.94	3.23	790	20	90.58	0.25
66157	3	collagen	-16.28	6.91	3.22	800	20	90.5	0.25
66158	4	collagen	-9.67	6.22	3.23	870	20	89.71	0.25
66159	5	collagen	-12.70	6.62	3.22	1200	20	86.11	0.24
66160	6	collagen	-13.97	7.03	3.19	880	20	89.61	0.25

The bone was cleaned by wire brush and washed, using ultrasonic bath. After cleaning, the sample was then reacted under vacuum with 1N HCl to dissolve the bone mineral and release carbon dioxide from bioapatite. The residue was filtered, rinsed with deionized water and under slightly acid condition (pH=3) heated at 80°C for 6 hours to dissolve collagen and leave humic substances in the precipitate. The collagen solution is then filtered to isolate pure collagen and dried out. The dried collagen was combusted at 575°C in evacuated/sealed Pyrex ampoule in the present CuO.
The resulting carbon dioxide was cryogenically purified from the other reaction products and catalytically converted to graphite using the method of Vogel *et al.* (1984) Nuclear Instruments and Methods in Physics Research B5, 289-293. Graphite ^{14}C/^{13}C ratios were measured using the CAIS 0.5 MeV accelerator mass spectrometer. The sample ratios were compared to the ratio measured from the Oxalic Acid I (NBS SRM 4990).
The sample ^{13}C/^{12}C ratios were measured separately using a stable isotope ratio mass spectrometer and expressed as δ^{13}C with respect to PDB, with an error of less than 0.1‰.
The quoted uncalibrated dates have been given in radiocarbon years before 1950 (years BP), using the ^{14}C half-life of 5568 years. The error is quoted as one standard deviation and reflects both statistical and experimental errors. The date has been corrected for isotope fractionation.

Sincerely,

Alexander Cherkinsky, Ph.D
Senior Research Scientist

120 Riverbend Road • Athens, Georgia 30602-4702
Telephone 706-542-1395 • Fax 706-542-6106 • www.cais.uga.edu
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The University of Georgia
Center for Applied Isotope Studies

RADIOCARBON ANALYSIS REPORT

March 1, 2024

Robert Madden
Colorado State University
1360 Walnut Street, Unit 201
Boulder, CO 80302

Dear Dr. Madden,

Enclosed please find the results of ^{14}C Radiocarbon analyses and Stable Isotope Ratio $\delta^{13}C$ analyses for the samples received by our laboratory on February 5, 2024.

UGAMS#	Sample ID	Material	$\delta^{13}C$,‰	$\delta^{15}N$,‰	C/N	^{14}C age, years BP	±	pMC	±
67768	5LO34-7	collagen	-11.65	8.19	3.31	830	20	90.14	0.25
67769	5LO34-8	collagen	-9.87	9.45	3.35	710	20	91.56	0.26
67770	5LO34-9	collagen	-16.6	6.59	3.44	740	25	91.18	0.26

The bone was cleaned by wire brush and washed, using ultrasonic bath. After cleaning, the sample was then reacted under vacuum with 1N HCl to dissolve the bone mineral and release carbon dioxide from bioapatite. The residue was filtered, rinsed with deionized water and under slightly acid condition (pH=3) heated at 80°C for 6 hours to dissolve collagen and leave humic substances in the precipitate. The collagen solution is then filtered to isolate pure collagen and dried out. The dried collagen was combusted at 575°C in evacuated/sealed Pyrex ampoule in the present CuO.
The resulting carbon dioxide was cryogenically purified from the other reaction products and catalytically converted to graphite using the method of Vogel *et al.* (1984) Nuclear Instruments and Methods in Physics Research B5, 289-293.
Graphite $^{14}C/^{13}C$ ratios were measured using the CAIS 0.5 MeV accelerator mass spectrometer. The sample ratios were compared to the ratio measured from the Oxalic Acid I (NBS SRM 4990).
The sample $^{13}C/^{12}C$ ratios were measured separately using a stable isotope ratio mass spectrometer and expressed as $\delta^{13}C$ with respect to PDB, with an error of less than 0.1‰.
The quoted uncalibrated dates have been given in radiocarbon years before 1950 (years BP), using the ^{14}C half-life of 5568 years. The error is quoted as one standard deviation and reflects both statistical and experimental errors. The date has been corrected for isotope fractionation.

Sincerely,

Alexander Cherkinsky, Ph.D
Senior Research Scientist

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The University of Georgia

Center for Applied Isotope Studies

RADIOCARBON ANALYSIS REPORT

August 21, 2024

Robert Madden
Colorado State University
1360 Walnut Street, Unit 201
Boulder, CO 80302

Dear Dr. Madden,

Enclosed please find the results of ^{14}C Radiocarbon AMS analyses and Stable Isotope Ratio δ^{13}C analyses for the samples received by our laboratory on July 24, 2024.

UGAMS#	Sample ID	Material	δ^{13}C,‰	^{14}C age, years BP	±	pMC	±
71030	5LO34-10	soot	-14.6	2540	25	72.9	0.22

The soot sample was treated following the acid/alkali/acid (AAA) protocol involving three steps: (1) an acid treatment (1N HCl at 80°C for 1 hour) to remove secondary carbonates and acid-soluble compounds; (2) an alkali (NaOH) treatment; and (3) a second acid treatment (HCl) to remove atmospheric CO2. Sample was thoroughly rinsed with deionized water between each step, and the pretreated sample was dried at 105°C. For accelerator mass spectrometry analysis the cleaned samples were combusted at 900°C in evacuated / sealed ampoules in the presence of CuO.

The resulting carbon dioxide was cryogenically purified from the other reaction products and catalytically converted to graphite using the method of Vogel *et al.* (1984) Nuclear Instruments and Methods in Physics Research B5, 289-293. Graphite ^{14}C/^{13}C ratios were measured using the CAIS 0.5 MeV accelerator mass spectrometer. The sample ratios were compared to the ratio measured from the Oxalic Acid II (NBS SRM 4990C). The sample ^{13}C/^{12}C ratios were measured separately using a stable isotope ratio mass spectrometer and expressed as δ^{13}C with respect to PDB, with an error of less than 0.1‰.

The quoted uncalibrated dates have been given in radiocarbon years before 1950 (years BP), using the ^{14}C half-life of 5568 years. The error is quoted as one standard deviation and reflects both statistical and experimental errors. The dates for all samples have been corrected for natural isotope fractionation except the standards and background targets, which have reported as δ^{13}C=-25‰. All results are reported without background correction.

Sincerely,

Alexander Cherkinsky, Ph.D.
Senior Research Scientist

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APPENDIX G
PATINATION: DISCUSSION AND DATA

As noted in Chapter Three, surveyors identified and collected a total of 134 samples of quarry reduction debris showing discernable surface patination from 67 of the 78 individual 1m^2 sub-units. Previous studies of patination on cryptocrystalline silicates have shown its formation tends to increase over time (Clark 1985; Frederick et al. 1994) such that the relative thickness of patination on chert, flint, and chalcedony artifacts can be, *but is not always*, indicative of their relative age as compared to less patinated specimens. This disconnect results from the fact that the rate of patination formation is heavily influenced not only by time, but also by the chemical composition of the base material, as well as by local climate conditions and soil types, patination intensity is generally not useful for comparing artifacts made of different materials exposed to different environmental conditions (Hurst and Kelly 1961; Pawlikowski, et al. 2014; Rottländer 1976; Schmalz 1960; VanNest 1985). Moreover, even where material and environmental variables are controlled, error rates for temporal assignments bases on patination thickness can still be significant for individual artifacts (Clark 1985; Frederick et al. 1994).

Nonetheless, in circumstances such as those presented here, where all of the patinated specimens considered are made of the same material, and all are from the surface of the same, limited (.57 km^2) area, where the same or similar weather and soil conditions are present, the findings of at least one study suggest that there is reason to expect that the relative thickness of patination could provide some rough indication, albeit not definitive, of the relative age of the specimens. Specifically, Fredrick et al. (1994) attempted to correlate patination levels with temporal periods, and then test those correlations, using patinated, temporally diagnostic projectiles points, made of the same raw material (Edwards chert) and collected from a spatially limited area (880 km^2). Frederick and his colleagues divided these artifacts into three groups based on the presence of relatively high, relatively low, or no patination, and assigned these groups to the Paleoindian period (high patination), the Archaic period (no patination), and the Late Prehistoric period (no patination) (1994:37-38). Because the patinated artifacts used by Frederick and his colleagues were temporally diagnostic, these patination-inferred temporal assignments could be, and were, tested for accuracy (1994).

Frederick and colleagues found that: (i) the assignment of high patination artifacts to the Paleoindian period had a 68% accuracy rate; (ii) the assignment of low patination artifacts to the Archaic period had an 81% accuracy rate; (iii) and the assignment of artifacts with no patination to the Late Prehistoric period had a 57% accuracy rate (Frederick et al. 1994:Table 6.1). Thus, while the error rate for temporal assignments based on the level of patination were high, these assignments were nonetheless more often than not (>50%) accurate for all time periods, with accuracy being significantly higher for assignments to the Paleoindian and Archaic periods (Table 6.1). Thus, this study demonstrates that the relative level of patination on artifacts made of the same material, exposed to similar environmental conditions, can have some (albeit limited) predictive value of age.

Moreover, there are reasons to believe that the patination-based, provisional temporal assignments made here would be more accurate than those made in the study by Frederick et al. (1994). First, the, artifacts used by Frederick and his coauthors were collected from sites in a zone spanning 880 km^2, which the authors noted likely created inconsistent environmental conditions (1994:Figure3.2). In contrast, all of the patinated artifacts at issue here were collected from an area of only .57 km^2, less than one tenth of 1% of the size of the Frederick et al. collection area. Additionally, as Frederick et al. noted, the Edwards chert used in their study is more heterogenous than other cryptocrystalline silicates (such as Flattop chalcedony), meaning that it would be more likely to form patination at irregular rates, given the importance of the chemical structure of the base material in patination formation (1994:37).

Finally, Frederick et al. correlated Late Prehistoric period artifacts with *no* patination rather than *low* patination (1994:37). This decision, as the authors later concluded, introduced error into their temporal assignments because "the lack of a patina says nothing about an artifact's age" (1994:38).[40] This error plainly contributed to the unusually high (47%) error rate observed by Frederick et al. for Late Prehistoric assignments (1994:Table 6.1), and likely increased the error rate for other time periods. In contrast, only patinated samples were included in the present study.

Here, the patination appearing on each of the 134 samples of quarry reduction debris showing discernable surface patination from the surface of 67 of the 78 individual 1m^2 sub-units was examined using low-power (20x) magnification, and the relative thickness of observed patination (the amount of color change caused by the desilicification process) appearing on each specimen was compared with the other samples. This resulted in a rank ordering of the 134 patinated samples from highest to lowest. The location by survey unit and rank-ordering of all patinated specimen collected[41] are set forth in Table 8 below. As discussed in Chapter Five, the relative patination observed on chalcedony debris recovered on the surface of Flattop Butte provided support for other, independent dating of certain locations and related features.

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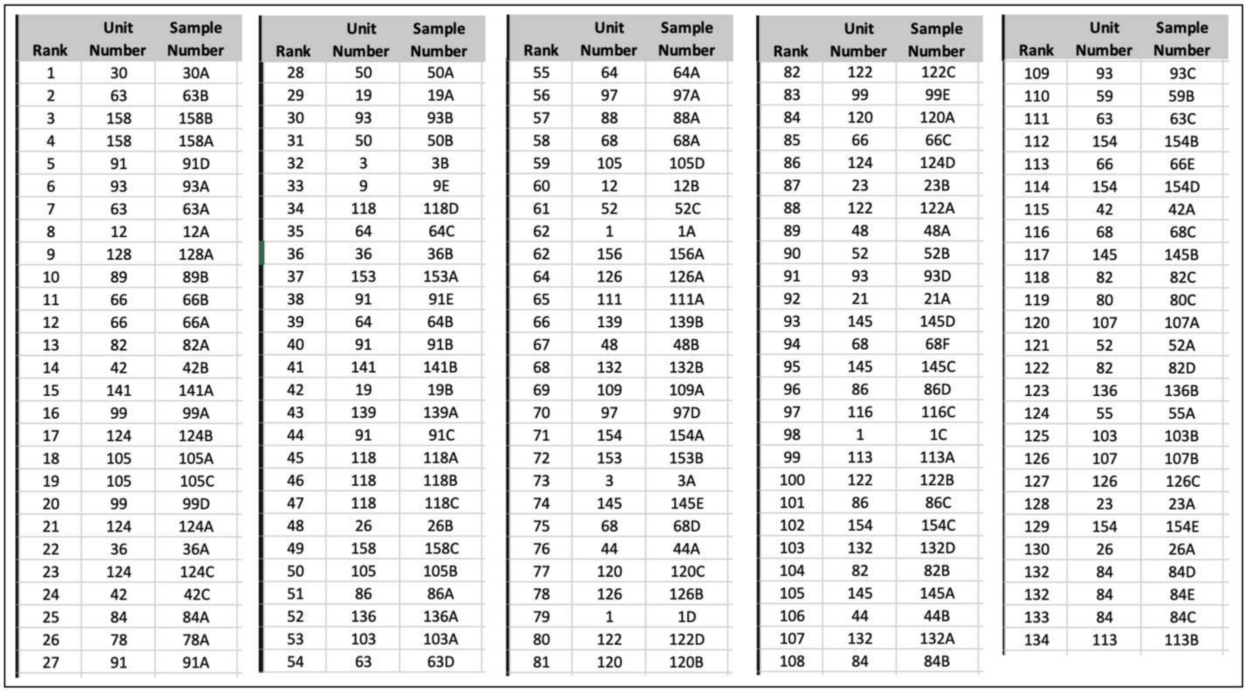
[40] The conclusion that the lack of patination is not indicative of a recent age was corroborated by an earlier study of patination on Knife River flint, a widely used lithic material in northwest Plains (Ahler and Christensen 1983:39).

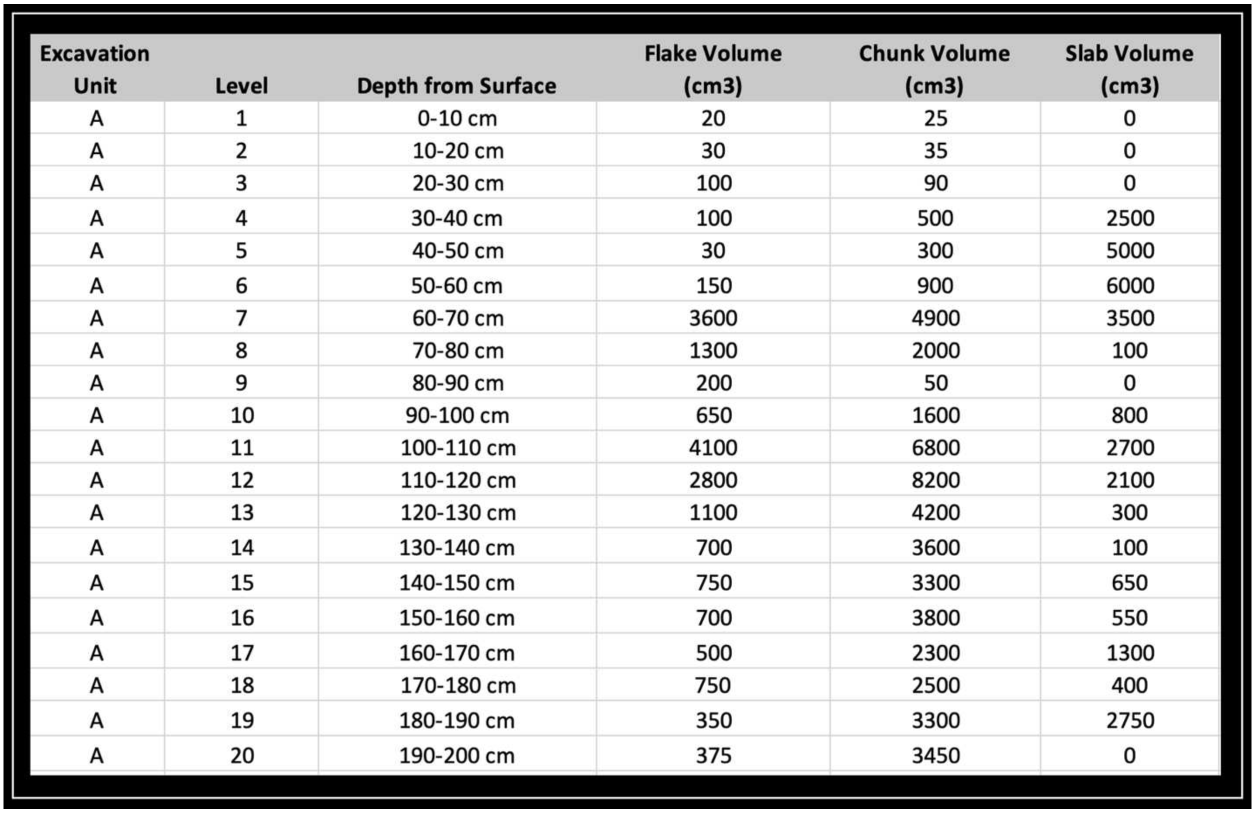
[41] For Units 147-159, where permission to collect was not permitted, patinated samples were photographed *in situ*.

Table 9. Patination data.



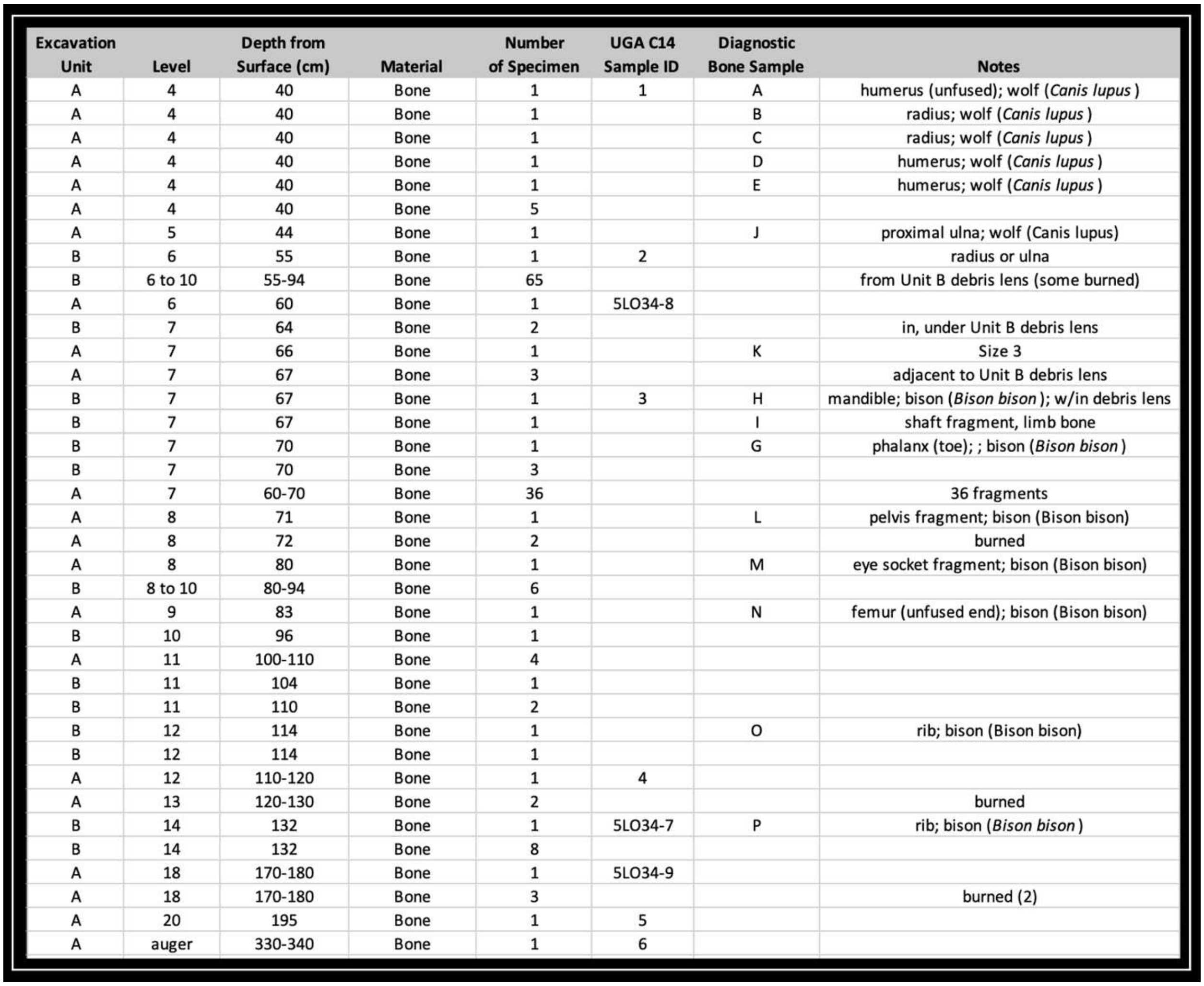
Rank	Unit Number	Sample Number
1	30	30A
2	63	63B
3	158	158B
4	158	158A
5	91	91D
6	93	93A
7	63	63A
8	12	12A
9	128	128A
10	89	89B
11	66	66B
12	66	66A
13	82	82A
14	42	42B
15	141	141A
16	99	99A
17	124	124B
18	105	105A
19	105	105C
20	99	99D
21	124	124A
22	36	36A
23	124	124C
24	42	42C
25	84	84A
26	78	78A
27	91	91A
28	50	50A
29	19	19A
30	93	93B
31	50	50B
32	3	3B
33	9	9E
34	118	118D
35	64	64C
36	36	36B
37	153	153A
38	91	91E
39	64	64B
40	91	91B
41	141	141B
42	19	19B
43	139	139A
44	91	91C
45	118	118A
46	118	118B
47	118	118C
48	26	26B
49	158	158C
50	105	105B
51	86	86A
52	136	136A
53	103	103A
54	63	63D
55	64	64A
56	97	97A
57	88	88A
58	68	68A
59	105	105D
60	12	12B
61	52	52C
62	1	1A
62	156	156A
64	126	126A
65	111	111A
66	139	139B
67	48	48B
68	132	132B
69	109	109A
70	97	97D
71	154	154A
72	153	153B
73	3	3A
74	145	145E
75	68	68D
76	44	44A
77	120	120C
78	126	126B
79	1	1D
80	122	122D
81	120	120B
82	122	122C
83	99	99E
84	120	120A
85	66	66C
86	124	124D
87	23	23B
88	122	122A
89	48	48A
90	52	52B
91	93	93D
92	21	21A
93	145	145D
94	68	68F
95	145	145C
96	86	86D
97	116	116C
98	1	1C
99	113	113A
100	122	122B
101	86	86C
102	154	154C
103	132	132D
104	82	82B
105	145	145A
106	44	44B
107	132	132A
108	84	84B
109	93	93C
110	59	59B
111	63	63C
112	154	154B
113	66	66E
114	154	154D
115	42	42A
116	68	68C
117	145	145B
118	82	82C
119	80	80C
120	107	107A
121	52	52A
122	82	82D
123	136	136B
124	55	55A
125	103	103B
126	107	107B
127	126	126C
128	23	23A
129	154	154E
130	26	26A
132	84	84D
132	84	84E
133	84	84C
134	113	113B

APPENDIX H:
QUARRY PIT DEBRIS FILL DATA



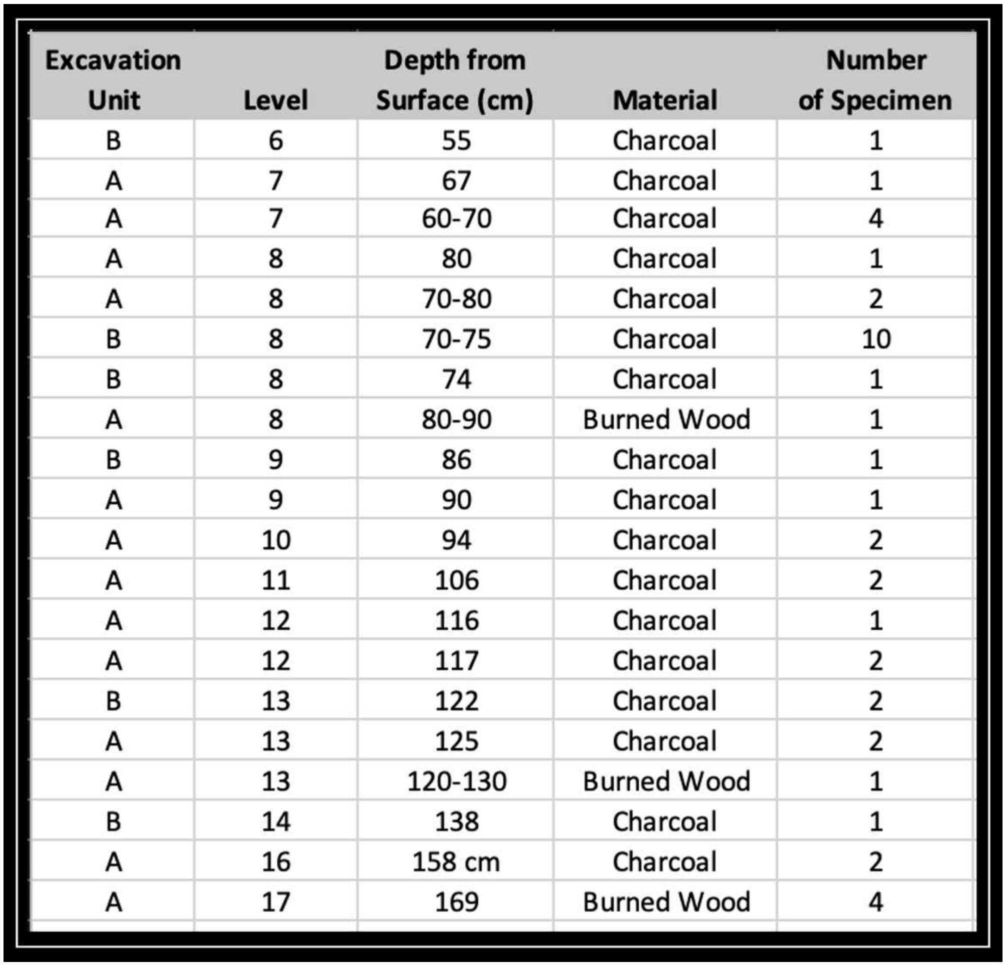
Excavation Unit	Level	Depth from Surface	Flake Volume (cm3)	Chunk Volume (cm3)	Slab Volume (cm3)
A	1	0-10 cm	20	25	0
A	2	10-20 cm	30	35	0
A	3	20-30 cm	100	90	0
A	4	30-40 cm	100	500	2500
A	5	40-50 cm	30	300	5000
A	6	50-60 cm	150	900	6000
A	7	60-70 cm	3600	4900	3500
A	8	70-80 cm	1300	2000	100
A	9	80-90 cm	200	50	0
A	10	90-100 cm	650	1600	800
A	11	100-110 cm	4100	6800	2700
A	12	110-120 cm	2800	8200	2100
A	13	120-130 cm	1100	4200	300
A	14	130-140 cm	700	3600	100
A	15	140-150 cm	750	3300	650
A	16	150-160 cm	700	3800	550
A	17	160-170 cm	500	2300	1300
A	18	170-180 cm	750	2500	400
A	19	180-190 cm	350	3300	2750
A	20	190-200 cm	375	3450	0

APPENDIX I:
FAUNAL REMAINS DATA



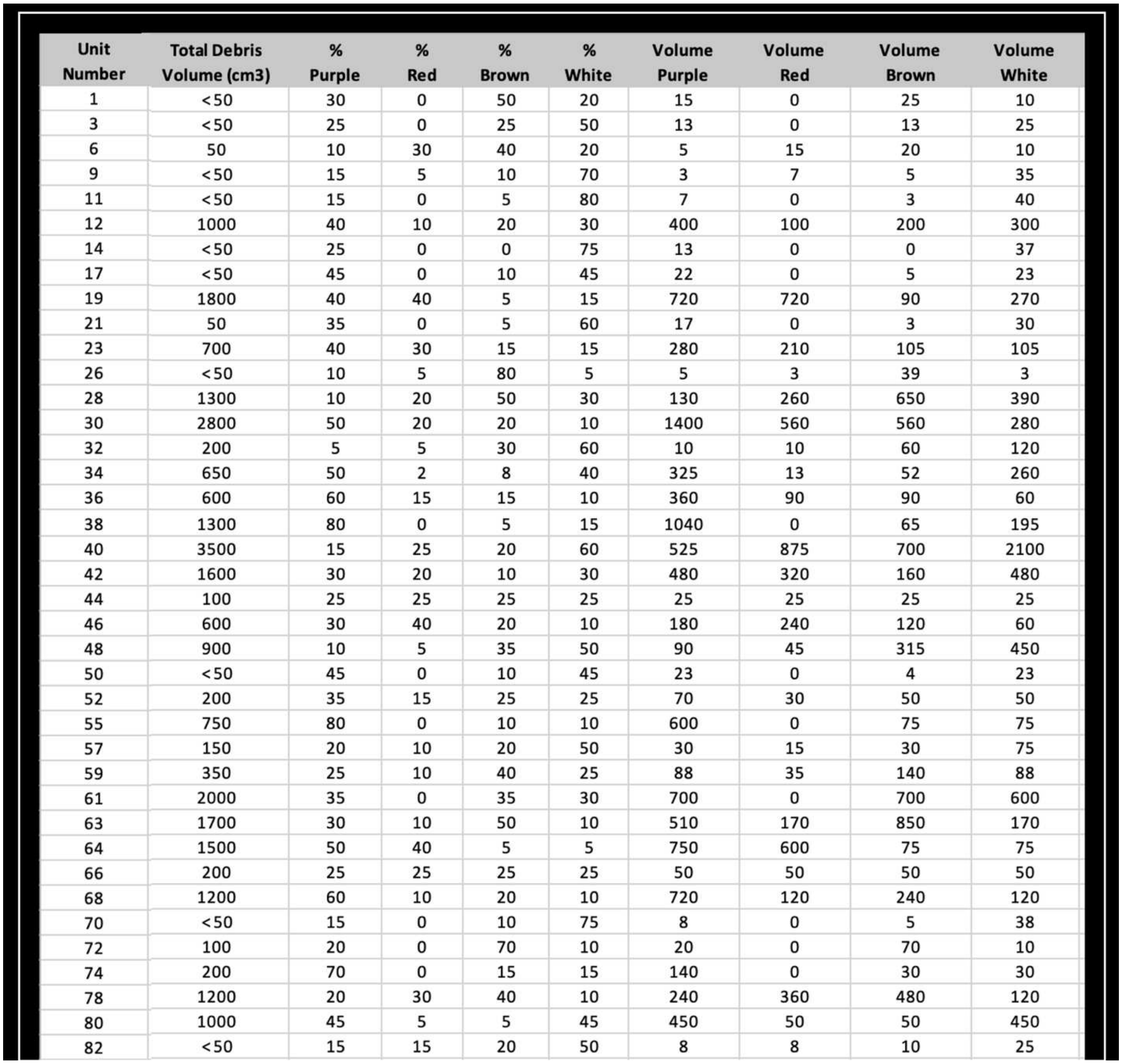
Excavation Unit	Level	Depth from Surface (cm)	Material	Number of Specimen	UGA C14 Sample ID	Diagnostic Bone Sample	Notes
A	4	40	Bone	1	1	A	humerus (unfused); wolf (*Canis lupus*)
A	4	40	Bone	1		B	radius; wolf (*Canis lupus*)
A	4	40	Bone	1		C	radius; wolf (*Canis lupus*)
A	4	40	Bone	1		D	humerus; wolf (*Canis lupus*)
A	4	40	Bone	1		E	humerus; wolf (*Canis lupus*)
A	4	40	Bone	5			
A	5	44	Bone	1		J	proximal ulna; wolf (Canis lupus)
B	6	55	Bone	1	2		radius or ulna
B	6 to 10	55-94	Bone	65			from Unit B debris lens (some burned)
A	6	60	Bone	1	5LO34-8		
B	7	64	Bone	2			in, under Unit B debris lens
A	7	66	Bone	1		K	Size 3
A	7	67	Bone	3			adjacent to Unit B debris lens
B	7	67	Bone	1	3	H	mandible; bison (*Bison bison*); w/in debris lens
B	7	67	Bone	1		I	shaft fragment, limb bone
B	7	70	Bone	1		G	phalanx (toe); ; bison (*Bison bison*)
B	7	70	Bone	3			
A	7	60-70	Bone	36			36 fragments
A	8	71	Bone	1		L	pelvis fragment; bison (Bison bison)
A	8	72	Bone	2			burned
A	8	80	Bone	1		M	eye socket fragment; bison (Bison bison)
B	8 to 10	80-94	Bone	6			
A	9	83	Bone	1		N	femur (unfused end); bison (Bison bison)
B	10	96	Bone	1			
A	11	100-110	Bone	4			
B	11	104	Bone	1			
B	11	110	Bone	2			
B	12	114	Bone	1		O	rib; bison (Bison bison)
B	12	114	Bone	1			
A	12	110-120	Bone	1	4		
A	13	120-130	Bone	2			burned
B	14	132	Bone	1	5LO34-7	P	rib; bison (*Bison bison*)
B	14	132	Bone	8			
A	18	170-180	Bone	1	5LO34-9		
A	18	170-180	Bone	3			burned (2)
A	20	195	Bone	1	5		
A	auger	330-340	Bone	1	6		

APPENDIX J:
CHARCOAL RECOVERED IN EXCAVATION UNIT



Excavation Unit	Level	Depth from Surface (cm)	Material	Number of Specimen
B	6	55	Charcoal	1
A	7	67	Charcoal	1
A	7	60-70	Charcoal	4
A	8	80	Charcoal	1
A	8	70-80	Charcoal	2
B	8	70-75	Charcoal	10
B	8	74	Charcoal	1
A	8	80-90	Burned Wood	1
B	9	86	Charcoal	1
A	9	90	Charcoal	1
A	10	94	Charcoal	2
A	11	106	Charcoal	2
A	12	116	Charcoal	1
A	12	117	Charcoal	2
B	13	122	Charcoal	2
A	13	125	Charcoal	2
A	13	120-130	Burned Wood	1
B	14	138	Charcoal	1
A	16	158 cm	Charcoal	2
A	17	169	Burned Wood	4

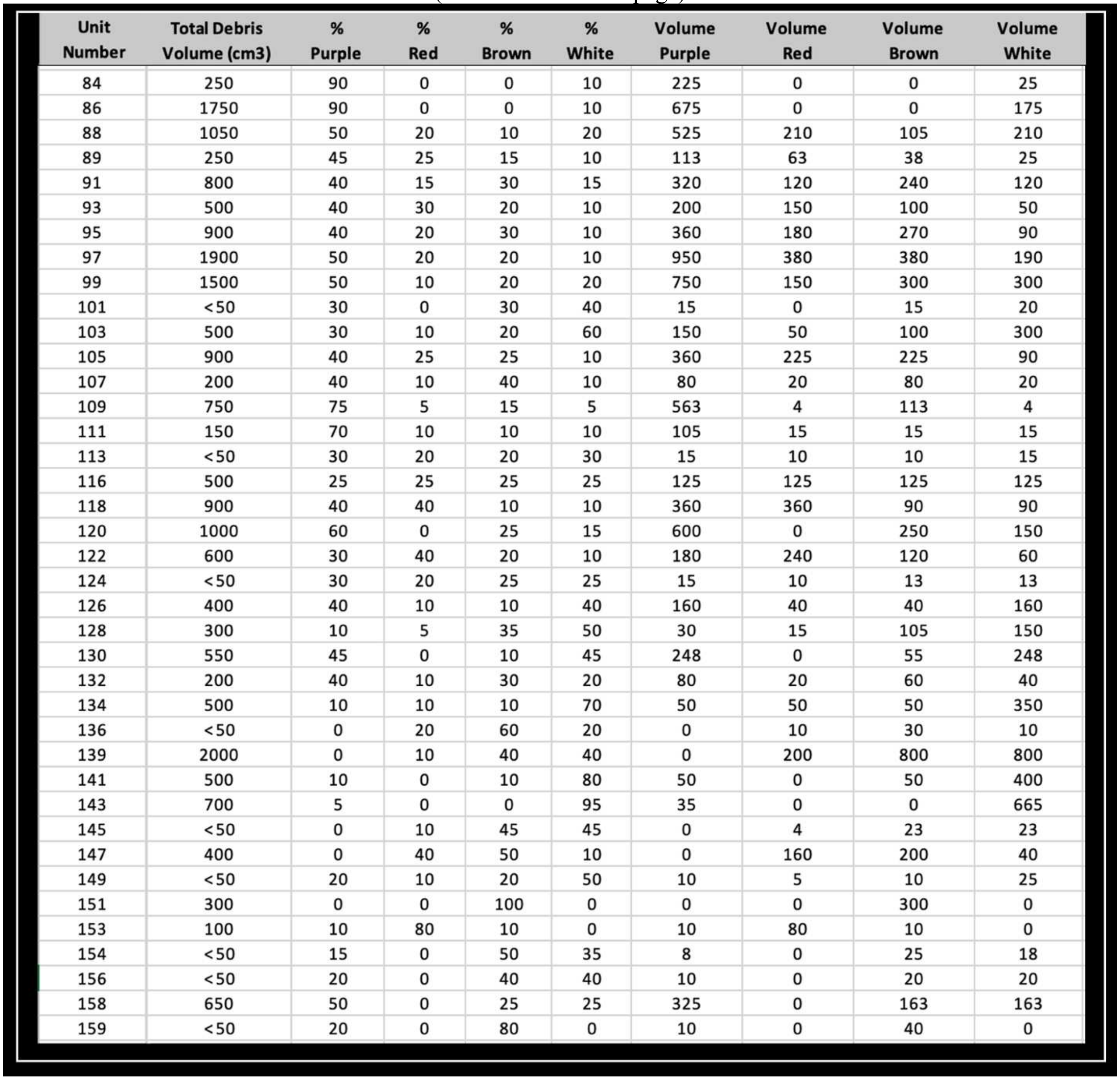
APPENDIX K:
HIGH-DENSITY DEBRIS AREA DATA



Unit Number	Total Debris Volume (cm3)	% Purple	% Red	% Brown	% White	Volume Purple	Volume Red	Volume Brown	Volume White
1	<50	30	0	50	20	15	0	25	10
3	<50	25	0	25	50	13	0	13	25
6	50	10	30	40	20	5	15	20	10
9	<50	15	5	10	70	3	7	5	35
11	<50	15	0	5	80	7	0	3	40
12	1000	40	10	20	30	400	100	200	300
14	<50	25	0	0	75	13	0	0	37
17	<50	45	0	10	45	22	0	5	23
19	1800	40	40	5	15	720	720	90	270
21	50	35	0	5	60	17	0	3	30
23	700	40	30	15	15	280	210	105	105
26	<50	10	5	80	5	5	3	39	3
28	1300	10	20	50	30	130	260	650	390
30	2800	50	20	20	10	1400	560	560	280
32	200	5	5	30	60	10	10	60	120
34	650	50	2	8	40	325	13	52	260
36	600	60	15	15	10	360	90	90	60
38	1300	80	0	5	15	1040	0	65	195
40	3500	15	25	20	60	525	875	700	2100
42	1600	30	20	10	30	480	320	160	480
44	100	25	25	25	25	25	25	25	25
46	600	30	40	20	10	180	240	120	60
48	900	10	5	35	50	90	45	315	450
50	<50	45	0	10	45	23	0	4	23
52	200	35	15	25	25	70	30	50	50
55	750	80	0	10	10	600	0	75	75
57	150	20	10	20	50	30	15	30	75
59	350	25	10	40	25	88	35	140	88
61	2000	35	0	35	30	700	0	700	600
63	1700	30	10	50	10	510	170	850	170
64	1500	50	40	5	5	750	600	75	75
66	200	25	25	25	25	50	50	50	50
68	1200	60	10	20	10	720	120	240	120
70	<50	15	0	10	75	8	0	5	38
72	100	20	0	70	10	20	0	70	10
74	200	70	0	15	15	140	0	30	30
78	1200	20	30	40	10	240	360	480	120
80	1000	45	5	5	45	450	50	50	450
82	<50	15	15	20	50	8	8	10	25

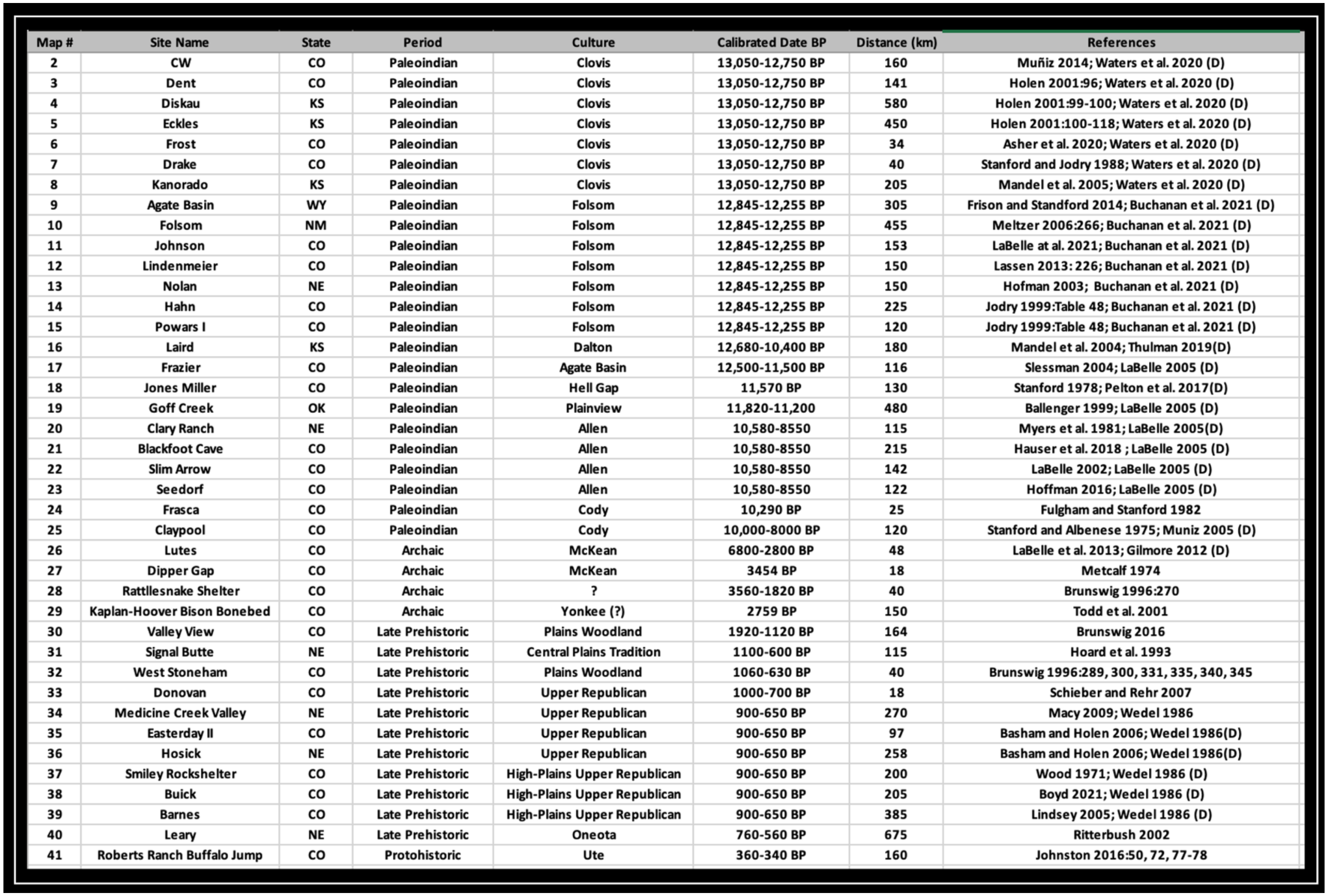
(continued on next page)

(continued from last page)



Unit Number	Total Debris Volume (cm3)	% Purple	% Red	% Brown	% White	Volume Purple	Volume Red	Volume Brown	Volume White
84	250	90	0	0	10	225	0	0	25
86	1750	90	0	0	10	675	0	0	175
88	1050	50	20	10	20	525	210	105	210
89	250	45	25	15	10	113	63	38	25
91	800	40	15	30	15	320	120	240	120
93	500	40	30	20	10	200	150	100	50
95	900	40	20	30	10	360	180	270	90
97	1900	50	20	20	10	950	380	380	190
99	1500	50	10	20	20	750	150	300	300
101	<50	30	0	30	40	15	0	15	20
103	500	30	10	20	60	150	50	100	300
105	900	40	25	25	10	360	225	225	90
107	200	40	10	40	10	80	20	80	20
109	750	75	5	15	5	563	4	113	4
111	150	70	10	10	10	105	15	15	15
113	<50	30	20	20	30	15	10	10	15
116	500	25	25	25	25	125	125	125	125
118	900	40	40	10	10	360	360	90	90
120	1000	60	0	25	15	600	0	250	150
122	600	30	40	20	10	180	240	120	60
124	<50	30	20	25	25	15	10	13	13
126	400	40	10	10	40	160	40	40	160
128	300	10	5	35	50	30	15	105	150
130	550	45	0	10	45	248	0	55	248
132	200	40	10	30	20	80	20	60	40
134	500	10	10	10	70	50	50	50	350
136	<50	0	20	60	20	0	10	30	10
139	2000	0	10	40	40	0	200	800	800
141	500	10	0	10	80	50	0	50	400
143	700	5	0	0	95	35	0	0	665
145	<50	0	10	45	45	0	4	23	23
147	400	0	40	50	10	0	160	200	40
149	<50	20	10	20	50	10	5	10	25
151	300	0	0	100	0	0	0	300	0
153	100	10	80	10	0	10	80	10	0
154	<50	15	0	50	35	8	0	25	18
156	<50	20	0	40	40	10	0	20	20
158	650	50	0	25	25	325	0	163	163
159	<50	20	0	80	0	10	0	40	0

APPENDIX L:
OFF-SITE OCCURENCES OF FLATTOP CHALCEDONY[42]



Map #	Site Name	State	Period	Culture	Calibrated Date BP	Distance (km)	References
2	CW	CO	Paleoindian	Clovis	13,050-12,750 BP	160	Muñiz 2014; Waters et al. 2020 (D)
3	Dent	CO	Paleoindian	Clovis	13,050-12,750 BP	141	Holen 2001:96; Waters et al. 2020 (D)
4	Diskau	KS	Paleoindian	Clovis	13,050-12,750 BP	580	Holen 2001:99-100; Waters et al. 2020 (D)
5	Eckles	KS	Paleoindian	Clovis	13,050-12,750 BP	450	Holen 2001:100-118; Waters et al. 2020 (D)
6	Frost	CO	Paleoindian	Clovis	13,050-12,750 BP	34	Asher et al. 2020; Waters et al. 2020 (D)
7	Drake	CO	Paleoindian	Clovis	13,050-12,750 BP	40	Stanford and Jodry 1988; Waters et al. 2020 (D)
8	Kanorado	KS	Paleoindian	Clovis	13,050-12,750 BP	205	Mandel et al. 2005; Waters et al. 2020 (D)
9	Agate Basin	WY	Paleoindian	Folsom	12,845-12,255 BP	305	Frison and Standford 2014; Buchanan et al. 2021 (D)
10	Folsom	NM	Paleoindian	Folsom	12,845-12,255 BP	455	Meltzer 2006:266; Buchanan et al. 2021 (D)
11	Johnson	CO	Paleoindian	Folsom	12,845-12,255 BP	153	LaBelle at al. 2021; Buchanan et al. 2021 (D)
12	Lindenmeier	CO	Paleoindian	Folsom	12,845-12,255 BP	150	Lassen 2013: 226; Buchanan et al. 2021 (D)
13	Nolan	NE	Paleoindian	Folsom	12,845-12,255 BP	150	Hofman 2003; Buchanan et al. 2021 (D)
14	Hahn	CO	Paleoindian	Folsom	12,845-12,255 BP	225	Jodry 1999:Table 48; Buchanan et al. 2021 (D)
15	Powars I	CO	Paleoindian	Folsom	12,845-12,255 BP	120	Jodry 1999:Table 48; Buchanan et al. 2021 (D)
16	Laird	KS	Paleoindian	Dalton	12,680-10,400 BP	180	Mandel et al. 2004; Thulman 2019(D)
17	Frazier	CO	Paleoindian	Agate Basin	12,500-11,500 BP	116	Slessman 2004; LaBelle 2005 (D)
18	Jones Miller	CO	Paleoindian	Hell Gap	11,570 BP	130	Stanford 1978; Pelton et al. 2017(D)
19	Goff Creek	OK	Paleoindian	Plainview	11,820-11,200	480	Ballenger 1999; LaBelle 2005 (D)
20	Clary Ranch	NE	Paleoindian	Allen	10,580-8550	115	Myers et al. 1981; LaBelle 2005(D)
21	Blackfoot Cave	CO	Paleoindian	Allen	10,580-8550	215	Hauser et al. 2018 ; LaBelle 2005 (D)
22	Slim Arrow	CO	Paleoindian	Allen	10,580-8550	142	LaBelle 2002; LaBelle 2005 (D)
23	Seedorf	CO	Paleoindian	Allen	10,580-8550	122	Hoffman 2016; LaBelle 2005 (D)
24	Frasca	CO	Paleoindian	Cody	10,290 BP	25	Fulgham and Stanford 1982
25	Claypool	CO	Paleoindian	Cody	10,000-8000 BP	120	Stanford and Albenese 1975; Muniz 2005 (D)
26	Lutes	CO	Archaic	McKean	6800-2800 BP	48	LaBelle et al. 2013; Gilmore 2012 (D)
27	Dipper Gap	CO	Archaic	McKean	3454 BP	18	Metcalf 1974
28	Rattlesnake Shelter	CO	Archaic	?	3560-1820 BP	40	Brunswig 1996:270
29	Kaplan-Hoover Bison Bonebed	CO	Archaic	Yonkee (?)	2759 BP	150	Todd et al. 2001
30	Valley View	CO	Late Prehistoric	Plains Woodland	1920-1120 BP	164	Brunswig 2016
31	Signal Butte	NE	Late Prehistoric	Central Plains Tradition	1100-600 BP	115	Hoard et al. 1993
32	West Stoneham	CO	Late Prehistoric	Plains Woodland	1060-630 BP	40	Brunswig 1996:289, 300, 331, 335, 340, 345
33	Donovan	CO	Late Prehistoric	Upper Republican	1000-700 BP	18	Schieber and Rehr 2007
34	Medicine Creek Valley	NE	Late Prehistoric	Upper Republican	900-650 BP	270	Macy 2009; Wedel 1986
35	Easterday II	CO	Late Prehistoric	Upper Republican	900-650 BP	97	Basham and Holen 2006; Wedel 1986(D)
36	Hosick	NE	Late Prehistoric	Upper Republican	900-650 BP	258	Basham and Holen 2006; Wedel 1986(D)
37	Smiley Rockshelter	CO	Late Prehistoric	High-Plains Upper Republican	900-650 BP	200	Wood 1971; Wedel 1986 (D)
38	Buick	CO	Late Prehistoric	High-Plains Upper Republican	900-650 BP	205	Boyd 2021; Wedel 1986 (D)
39	Barnes	CO	Late Prehistoric	High-Plains Upper Republican	900-650 BP	385	Lindsey 2005; Wedel 1986 (D)
40	Leary	NE	Late Prehistoric	Oneota	760-560 BP	675	Ritterbush 2002
41	Roberts Ranch Buffalo Jump	CO	Protohistoric	Ute	360-340 BP	160	Johnston 2016:50, 72, 77-78

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[42] References in the table with a "D" provide dating for the referenced site or cultural complex.