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Late Pleistocene and Holocene *Bison* of Grand Canyon and Colorado Plateau: Implications from the use of Paleobiology for Natural Resource Management Policy

A thesis
presented to
the faculty of the Department of Geosciences
East Tennessee State University

In partial fulfillment
of the requirements for the degree
Master of Science in Geosciences

by
Jeff M. Martin
May 2014

Jim I. Mead, Chair
Blaine W. Schubert
Steven C. Wallace

Keywords: Bison, Grand Canyon, Paleontology, Conservation, Geospatial, Paleobiology

ABSTRACT

Late Pleistocene and Holocene Bison of Grand Canyon and Colorado Plateau: Implications from the use of Paleobiology for Natural Resource Management Policy

by

Jeff M. Martin

Bison spp. (bison) fossils are scarce on the Colorado Plateau, especially within the greater Grand Canyon region. Because of the poor fossil record for bison on the plateau and in Grand Canyon National Park, various resource managers have surreptitiously designated bison a nonnative and human-introduced species. The lack of evidence for bison seems to be the result of collection bias rather than a true lack of bison remains. Today, Grand Canyon National Park has a neighboring herd of 350 bison that have meandered unwantedly onto National Park lands from neighboring Forest Service and State of Arizona lands. This study spatiotemporally illustrates bison are recently native to the greater Grand Canyon area based on previously misidentified specimens in archaeological collections. Data here may require resource managers to reconsider whether or not bison should be reconsidered a native species to the Grand Canyon National Park and elsewhere on the Colorado Plateau.

DEDICATION

I dedicate this project to all of the bison enthusiasts, ranchers, and researchers out there; keep ruminating about bison!

Some of these bison enthusiasts, ranchers, and researchers have influenced my life from an early start and are responsible for the success of this project. Starting with my parents, Tom and Kris Martin, for bringing me into this world, raising me on bison ranch in Wisconsin, and encouraging my love of bison and nature. Next is Gail Griffin who has supported my every move along the way academically and, more importantly, had to listen to my parents talk about me at bison conventions.

I also dedicate this to all of the paleo-minded folks out there studying, collecting, and loving fossils. I want to distinguish my advisor, Jim Mead, who has inspired both my research project and my aspiration to pursue my doctorate at the University of Maine.

Finally, I dedicate this to the most important person in my life, Rachel Short, my fiancé. You are my love, my confidant, and my best friend. You encourage and push me to be the best that you know I can be. Thank you!

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Funding sources are increasingly difficult to obtain for exploratory science. To my avail, I obtained funding from two generous and research oriented avenues. First, the National Buffalo Foundation procured $1,400 for the dedicated use of radiocarbon dating some of my samples. I generously thank the National Buffalo Foundation for funding my research! Second, Experiment.com, previously Microryza.com, provided a platform for me to explain my project goals and request crowd-source funding to achieve those goals. I thank all of the donors that supported my research in all amounts of donations. A big thank you to the creators of Experiment.com and to the financial supporters of my project: Pat Monaco, Aimee Finn, Jason P. Schein, Skander Mzali, user Hello World, Denny Luan, Amy Billings, Jeffrey Supplee, Carolyn Gilmore, Laura Gilmore and Evan Emmert, Nancy Greenwood, April Carr, Rachel Pike, Jennifer Barber, Linda Cox, Kimber Short, Andrew Joyner, Sandra Swift, Gail Griffin, Ginger Keller-Ferguson, and Kayla Badamo. Additionally, ETSU Don Sundquist Center of Excellence in Paleontology provided monies for data collection travel to the Grand Canyon and other museum collections along with the ETSU Graduate School Graduate Student Research Grant. Thank you!

I would also like to thank the generous Ron Blakey for supplying the beautiful paleo-reconstructions of the geomorphology of the Colorado Plateau for the background used in my analysis. It greatly improved the quality of the appearance of my maps!

Thank you to my friends, colleagues, and other grad students in the paleo-community who have all, through many beers and discussions, been involved with listening to me talk about bison, literally, all the time. Especially, Kevin Chovanec! May there be many man-dated coffees!

The ETSU Geosciences Department faculty and staff for providing outstanding courses that push the students to be inquisitive and to think critically about the world around them. I would like to especially thank some department members: Dr. Blaine Schubert for providing many opportunities for field collection of fossils in Saltville, Virginia and collection of reptiles and amphibians in South Carolina; Dr. Steven Wallace for providing statistical course work for geometric morphometrics and expanding our critical thinking of peer reviewed science papers. Dr. Eileen Ernenwein for providing me the skills and knowledge to use ArcGIS and other geospatial tools and Dr. Andrew Joyner for expanding my skills with geospatial tools and providing suggestions to improve the geospatial analysis of this thesis.

I would also like to thank Dr. Jim Mead for providing the knowledge and patience of teaching us about biochronology, rodents, taphonomy, ungulates; similarly, Sandra Swift for assisting our understanding of Photoshop and helping us find, catalog specimens in the East Tennessee Vertebrate Paleontology collections, and for genuinely caring for the student’s advancement of knowledge. Each member has provided valuable knowledge and skills that are irreplaceable and have created a foundation for not just me, but all of the graduate students at ETSU to flourish. Thanks to you all!

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CHAPTER 1

INTRODUCTION

> *"Here is your country* [in reference to the Grand Canyon]. *Do not let anyone take it or its glory away from you! Cherish these natural wonders, cherish the natural resources, cherish the history and romance as a sacred heritage, for your children and your children's children. Do not let selfish men or greedy interests skin your country of its beauty, its riches or its romance. The world and the future and your very children shall judge you according as you deal with this sacred trust."*
>
> —Theodore Roosevelt, excerpt from a speech on May 6, 1903, at the Grand Canyon.

Overview

I report here on the paleontological and archaeological localities known to contain *Bison* from the Grand Canyon and Colorado Plateau. Often, *Bison* remains are found in museum collections as unreported specimens, misidentified as *Bos*, or labeled "large ungulate". Clearly, the 'official' record about *Bison* on the Colorado Plateau (CP) is incomplete and misrepresented. The study here is important because it provides an updated paleontological and archaeological record of *Bison*'s existence on the CP, especially recently in the greater Grand Canyon area (GGC). These disciplines, together, answer the main questions – where were the bison and what age are they? Some researchers postulate how and why the bison are found where they are currently because: 1) *Bison* could be naturally inhabiting the region of the locality, 2) *Bison* might not be common where found but due to a rare dispersal event they occurred outside their ‘normal’ range, 3) *Bison* could have died and been washed into and along the Colorado River well away from where they are found as a fossil, a bloat-and-float from upstream scenario, and 4) prehistoric *Bison* found in some archaeological scenarios could be ‘goods’ traded by peoples from lands where *Bison* is more common.

This study attempts to answer these questions through paleozoological investigation of 65 sites on and around the CP that have *Bison* remains. The paleozoological data are then displayed spatially and analyzed spatiotemporally to visualize the nativity of *Bison* on the CP. From the spatiotemporal analysis, conservation implications result. To facilitate conservation discussion, ecological differences and implications of *Bison* and *Bos* are examined.

Background

Recent studies by Reimondo (2012) and Huffer (2013) that included archaeological and environmental assessments of the ecological impacts and nativity of the American bison (*Bison*; Order Artiodactyla, Family Bovidae, Subfamily Bovinae, Tribe Bovini) in the Grand Canyon National Park (GRCA) and elsewhere on and around the CP. However, the genus, as of now, should be considered a working unit and not definitive until more evidence is available to make a substantiated statement. Thus, I use *Bison* out of convention, paleontologically.

Their work deserves intensive scrutiny because they lack information from paleontological resources as well as historical and modern zoogeography. The study here delves into each dataset and analyzes all of the details to provide a more complete spatiotemporal assessment of bison’s presence on the CP.

Perhaps no other extant animal in North America shares the cultural, spiritual, ecological, economic, political, and natural history as the North American plains bison (*Bison bison bison*) (Isenberg 1997; Lodge and Shrader-Frechette 2003; Sanderson et al. 2008); certainly, no other animal has the story of surviving the brink of extinction twice! This survival does not stop at our North American plains species but the same is true for the North American woods bison (*Bison bison athabascae*) along with the European bison, also known as the wisent (*Bison bonasus*). First, at the end of the Pleistocene-11,700 Calendar years B.P. (hereafter referred to as: years B.P.), *Bison* outlived mammoths (*Mammuthus*), mastodons (*Mammut*), horses (*Equus*), giant ground sloths (*Megalonyx* and others), and other megafauna while coexisting with early Americans, Paleoindians. Second, Americans of European-descent, during the late 1800s AD, purposefully hunted the bison until it was nearly extinct. As an aside, equally devastating, the wisent was hunted as food during World War I to near extinction in Europe (Pucek et al. 2004). Today, bison numbers in North America have reached nearly half a million (Boyd and Gates 2006; Gates et al. 2010). The National Bison Legacy Act was introduced to Congress in 2013 and, as a result, the North American bison is the symbolic national mammal of the United States.

Today, there are 2 disputed subspecies of *Bison* (Cronin et al. 2013). 1) *Bison bison bison* was historically found in the Great Plains, yet today there are private bison ranches that have plains bison in every state within the U.S.A. and 2) *Bison bison athabascae* was historically found north of 49 °N latitude in Canada and Alaska. This project does not address subspecies and focuses on the species *Bison bison* as well as the presumed fossil relative, *Bison antiquus*, because it has also been reported on the CP and in the surrounding provinces.

Late Pleistocene and Holocene (as used in this study: 22,100 years B.P. to today) remains of *Bison* spp. are known from southern Arizona, the Great Plains, the Rocky Mountains, and the Great Basin. However, records of *Bison* from the CP and the GGC are inadequately known (McDonald 1981; McClaran and Van Devender 1995; Mead 2002). The CP, GRCA, Kaibab National Forest (North Rim only; KNF), and GGC are all geographically defined in Figure 1.

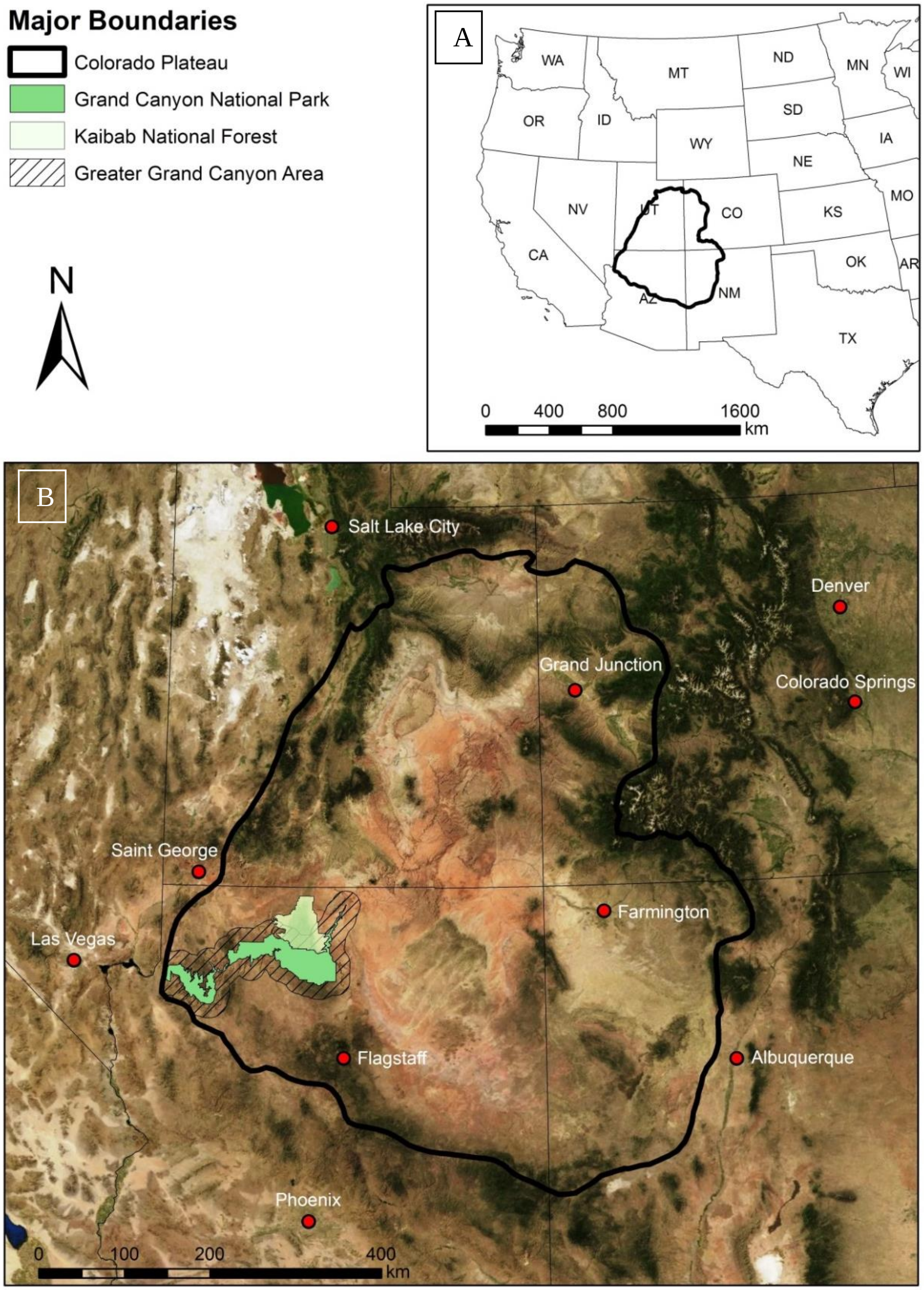


Figure 1. Georeference Map. A) Position of the Colorado Plateau (CP) within the United States. B) Relation of the Grand Canyon National Park (GRCA), Kaibab National Forest (KNF), and the greater Grand Canyon area (GGC) (defined as a 10 mile (16 km) buffer from the boundary of GRCA only on the CP) (satellite imagery of the CP).

Throughout the Holocene *Bison* relative abundances varied over most of North America possibly due to hunting and intraspecific competition; yet, the population steadily increased until European contact when their abundance probably reached their climax (Flores 1991; as discussed in McClaran and Van Devender 1995). This increase may have occurred because of limited trophic-equivalent competition (Flores 1991), along with reduced abundance and diversity of the bison's presumed predators since the Ice Age extinction of the dire wolf (*Canis dirus*), American lion (*Panthera atrox*), and the giant short-faced bear (*Arctodus simus*) (Flores 1991). Thus, the observations made by early western explorers (Hornaday 1889) of the abundance of bison are misleading (Flores 1991). Furthermore, bison earlier in the Holocene were less abundant in the Great Plains but were intermittently present in the southwest (McClaran and Van Devender 1995; Broughton et al. 2008).

There are multiple factors contributing to the seemingly poor fossil record of *Bison* for the Late Pleistocene and Holocene on the CP. The region is incompletely studied by Quaternary paleontologists and zooarchaeologists compared to the neighboring provinces, most likely due to remoteness. In addition, the CP as a whole is 'unroofing' (Flowers et al. 2008; Karlstrom et al. 2012) and, as a result, surficial eroding of open-air sites is continuously destroying and removing the fossil history. The GGC (Figure 1B) is defined here as the inclusion of GRCA and the 16 km (10 mi) radius around the border of GRCA and on the CP, which includes the physiographically similar areas adjacent to the Grand Canyon Rims, i.e. – the GGC does not include Lake Mead region.

Geology of CP

Tectonically, in recent history (~20,000 years ago to present), the CP has been stable with minimal deformation (Kent and Witte 1993; Mutschler et al. 1997). However, earthquakes of small magnitude do occur. The CP averages from 35 kilometers (22 miles) thick near the flanks of lower elevation to 50 kilometers (31 miles) thick near the center alpine regions. The rocks exposed by the Colorado River record a supersequence of formations that can be seen in Grand Canyon, Zion, Bryce Canyon, Canyonlands/Arches, and Mesa Verde National Parks, which collectively comprise the Grand Staircase (Blakey 2009; Whittaker 2012).

The last 2.588 million years of Earth's history is known as the Quaternary Period (Cohen et al. 2013), which is characterized by drastic climate changes including the Ice Ages. During the Ice Ages, alpine glaciers in the neighboring Rocky Mountains shaped the distinctive valleys in the mountains and outwash flowed westward into what is now the Colorado River. This outwash flushed the gorge, incised, and widened the Grand Canyon to its current morphology, which will only continue to widen and deepen as long as there is a water source (Ranney 2012). This water source is also the attractant for life on the CP. Animals, especially during the drought-like conditions of the Bølling-Allerød (12.9 – 14.7 ka), which is the most severe conditions seen over the past 46,000 years (Polyak et al. 2012), were drawn to the rivers by the presence of drinking water. The harsh conditions during this time may be the cause for the astounding lack of bison fossils on the CP.

Local and Regional Setting. The basement rocks of the CP were deposited as mainly shales, silts, and other marine sediments near a fluvial delta from a terrestrial setting (Powell 1875). The basement rocks are deformed by the ancestral Mazatzal orogeny that occurred during the middle to late Proterozoic Eon and metamorphosed the sediments into the Vishnu Schist (Blakey 2009). Since their upheaval, the mountains have eroded back to flat surface and were covered by several Paleozoic and Mesozoic transgressions. They were uplifted twice again in the Laramide orogeny of the late Cretaceous Period and in an independent post-Laramide orogeny during the Eocene Epoch (Blakey 2009). These orogenic cycles combined with erosional ‘unroofing’ periods created the modern Rocky Mountains and CP (Flowers et al. 2008). One hypothesis to explain these uplifts and rotation claims that plate subduction at the western edge of the North American Plate created mantle convection that resulted in differences of mantle buoyancy and density (Reiter and Chamberlain 2011; Whittaker 2012).

Quaternary Geomorphology and Ecology of the Colorado Plateau and the Grand Canyon.

The surface geomorphology of the CP is due, in part, to the uplift of the Laramide Orogeny to its present altitude and, in part, to the erosional preferences of certain rock types from the outwash of glacier melt from the last Ice Age, and as a result, creating the Colorado River (Ranney 2012; Whittaker 2012). As shown in Figure 2 during the Ice Age, illustrated by the lighter white areas, mountaintops that were capped with alpine glaciers that supplied the Colorado River with glacial melt (Blakey and Ranney 2008). During this time the Salt Lake City area in Utah was covered by a pluvial paleo-lake known as Lake Bonneville. Lake Bonneville was a large body of water, as deep as 300 meters, and when it discharged, the water flowed north into the Snake River Basin. However, the Colorado River, Green River, and the Little Colorado River are the main watersheds of the CP, all of which flow southward and the latter 2 empty into the Colorado River further incising the Grand Canyon. Most of the Pleistocene aged sites are located in these river basins, which indicate that *Bison*, *Euceratherium*, *Mammut*, *Mammuthus*, camels, giant ground sloths, and other Ice Age faunal taxa that are preserved in caves and alcoves inside the canyons were common in the area during the Pleistocene.

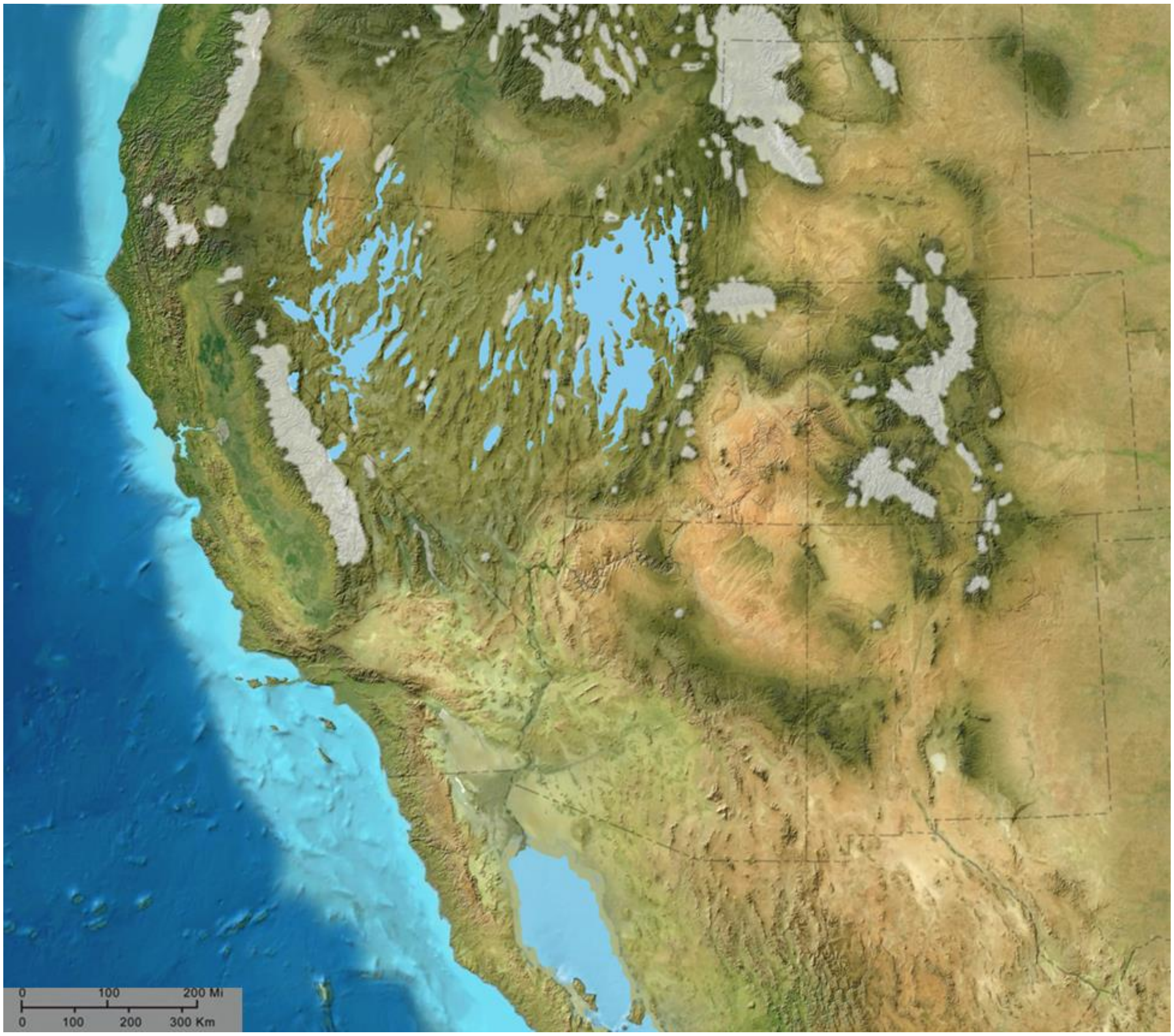


Figure 2. Pleistocene (150-25 Ka) geomorphology of the Colorado Plateau and Southwestern North America. Notice the presence of the Grand Canyon, the Kaibab upwarp bisected by the Colorado River, and the mountaintops are glaciated (alpine glaciers; transparent white color). Modified from Blakey and Ranney (2008).

However, at the end of the Pleistocene, many faunal taxa went extinct and those species that did survive, including *Bison*, had to adapt to a rapidly changing climate. In doing so, these species (both faunal and floral) migrated up- or down-slope to follow the moving biomes in response to temperature and precipitation changes. Notice the vegetation cover difference of Figure 2 and Figure 3. The transition from the Pleistocene (Figure 2) to the Holocene (Figure 3) included desertification of much of the western United States. Throughout the late Holocene, climate has remained relatively constant except for the Little Ice Age (1550 AD – 1850 AD). The Little Ice Age was particularly cold and wet for most of the globe and happens to have occurred at the same time as the Lewis and Clark expedition, who were traveling through the Great Plains. Some theorize the Little Ice Age was the peak population period for bison in all of history (Flores 1991) due to favorable climatic conditions for grasses and the bison, which had no perceived large predators as they did during the last Ice Age. Due to colder conditions during the ice ages, the flora and fauna responded to the climatic pressures by moving downslope or south to maintain preferential temperatures as illustrated in Figure 4 (Cole 1985; Weng and Jackson 1999; Anderson et al. 2000; Zhu et al. 2014).

Figure 3. Ca. 1930s (Pre-Glen Canyon and Hoover/ Boulder Dams) geomorphology of the Colorado Plateau and the Southwest U.S. Notice the presence of the Grand Canyon, and the Kaibab upwarp bisected by the Colorado River. Modified from Blakey and Ranney (2008).

Brief Historical Review of *Bison* near the Grand Canyon

The historical history of bison in the Southwest is complex. Northern Arizona has scarce historical records but the Spanish reported a small herd of *Bison* in the 16th century in East-central New Mexico (Reed 1952), adjacent to the CP. Native Americans in the 1200s AD and earlier (Reed 1952), used the bones of bison at archaeological sites and created pictographs of this bovid on the walls of Kanab Creek near Kanab, Utah (Malotki and Wallace 2011). However, the ideas, memories, and thoughts that inspired these paintings may have traveled great distances, well beyond the actual zoogeographic distributions bringing the origin of the bison in the pictographs and petroglyphs into question. Although a few documented occurrences confirm that bison frequented the CP near the Grand Canyon in small but apparently sustainable herds (Seager et al. 2007). These herds most likely had relatively large home ranges to endure the low carrying capacity of the region (Seager et al. 2007). Using ArcGIS in Chapter 2 and 3, a spatiotemporal analysis describes and examines this in detail.

In 1905 Arizona wildlife diversity experienced an influx of bison to the North Rim of what is now GRCA when Charles J. “Buffalo” Jones brought bison to the Kaibab Plateau (Hoffmeister 1986) and crossbred them with cattle to create a hardy livestock animal he called ‘cattelo’ (hereafter referred to as cattalo). In 1906 when Congress established the Grand Canyon Game Preserve, they listed bison as one of the wildlife species that should be maintained on the Kaibab Plateau (unpublished report to U. S. Congress, Protection of Wild Animals in the Grand Canyon Forest Preserve). The Kaibab Plateau was described as "ideal for buffalo [*Bison*], deer and other wild game" and was “to be recognized as a breeding place therefore” (Wakeling 2006). Most importantly, “the Preserve was created on 28 November 1906 by President Theodore Roosevelt and is still in effect. It predates the establishment of the [Kaibab] National Forest [in

1909], Grand Canyon National Park [in 1919], and the Arizona Game and Fish Commission [in 1913]" (Wakeling 2006: 25). These bison were then relocated east to the House Rock Valley because of the creation of the Kaibab National Forest until C.J. Jones moved all but 15-20 animals out of the area in 1909. The remaining animals became property of James T. "Uncle Jim" Owens and, by 1927, the herd had increased to 98 individuals and was purchased by the State of Arizona.

Over the last half century, introduced purebred bison from Oklahoma and Montana were added to the herd (Hoffmeister 1986). In 1942, in an attempt to purify the herd, 12 bison bulls were relocated from the Wichita Wildlife Refuge in Oklahoma to the House Rock Valley bison herd and 6 more were added in 1946. Three bison were relocated in 1980 to the House Rock Valley bison herd from the Montana Bison Refuge; "under present conditions, the [House Rocky Valley bison] herd seem to be doing well" (Hoffmeister 1986: 560). In 2000, 5 bison females and 1 bison male were relocated to the House Rock Valley bison herd from the Henry Mountains, Utah (Arizona Game and Fish Department (AZGFD), unpublished data; (Wakeling 2006)). The continued addition of new pure bison genetics improve the genetic integrity of the herd and slowly this has and will increase the genetic purity of the herd over time.

Paleozoologic Records Applied to Public Policy and Resource Management

Paleozoological resources increase the knowledge base of how environments change over time. By studying and comparing pre-anthropogenic (natural), anthropogenic (human altered), pre-Colombian (pre-European contact), and post-Colombian (post-European contact) eras, well-informed resource management decisions can be made. These data provide information about how ecosystems have been lost, adapted, recolonized, or developed and are important for "restoring" or "preserving" a particular ecosystem. The cause for preservation or restoration may be driven by political, social, economic, or ecological factors (Lyman and Cannon 2004; Lyman 2006).

Public Policy Definitions

Many federal agencies manage their landscapes and biotas to be natural, pristine, and native and usually defined in terms of “pre-Columbian or immediately post-Columbian” (Lyman 2006). This post-Columbian ideology ignores not only the thousands of years of Native American occupation in North America prior to Columbus’s discovery in 1492 AD, but also the seemingly countless years before any people set foot in North America (before approximately 14,000 years B.P.). Regardless of the practices to manage the landscapes, management officials and decision makers have a responsibility to communicate with research scientists for the ‘proper’ biome eco community to conserve and the ‘proper’ methods of achieving the desired ‘pristineness’, which in itself can be subjective (Hunter 1996; Lyman and Cannon 2004).

Scientists in the past have traditionally thought that *Bison* are not native to the CP or the GRCA, thus *Bison* conservation doesn’t have a precedent set for the CP. Due to inadequate perimeter fencing, the National Park Service (NPS) has an “invasive” herd of approximately 350 “nuisance” bison roaming and inhabiting the Powell Plateau (Holton pers. comm. 2013) of the North Rim (Larson et al. 2009). These bison (House Rock Valley bison) are property of the State of Arizona in the House Rock Valley Wildlife Area (HRVWA), east of the Kaibab Plateau and the Kaibab National Forest (KNF). Understanding the following definitions used to describe the House Rock Valley bison is vital. The US Federal Government and the NPS define an invasive species as “an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health” (Executive Order 13112 Section 1) and “those species that occupy or could occupy park lands directly or indirectly as the result of deliberate or accidental human activities" (U.S. Dept. of the Interior and National Park Service 2006). Similarly, a native species is "with respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem" (Executive Order 13112 Section 1) and "all species that have occurred, now occur, or may occur as a result of natural processes on lands designated as units of the national park system… [and] are evolving in concert with each other" (U.S. Dept. of the Interior and National Park Service 2006).

Moreover, the state of Arizona defines "wild" as "in reference to mammals and birds, those species which are normally found in a state of nature" and "wildlife" as "all wild mammals, wild birds and the nests or eggs thereof... including their eggs or spawn" (Arizona Revised Statutes, Title 17 – Game and Fish, Chapter 1, Article 1, Section A, 22-23). Such Arizona wildlife includes "game mammals [being] deer, elk, bear, pronghorn (antelope), bighorn sheep, bison (buffalo), peccary (javelina), mountain lion, tree squirrel and cottontail rabbit" (Arizona Revised Statutes, Title 17 – Game and Fish, Chapter 1, Article 1, Section B, 2). A more inclusive and succinct definition of how to consider and manage exotic, nonnative, and native animals may be found in Cannon (2001), Lyman (2006), de Queiroz (2007), and Stronin and Paquet (2013).

However, some use Arizona Revised Statutes 3-1401 (Title 3 – Agriculture) to argue that in the state of Arizona bison are not wildlife but "stray animals" defined as "livestock, bison or ratites whose owner is unknown or cannot be located, or any such animal whose owner is known but permits the animal to roam at large on the streets, alleys, roads, range or premises of another without permission, except that this section does not apply to livestock where the principles of a federal permit, federal allotment or federal lease are in dispute." Here, the argument is invalid because the bison found on the North Rim of GRCA and KNF are known to be property of the State of Arizona Game and Fish Department whose bison sanctuary predates the federal allotment of GRCA and KNF (Wakeling 2006), which causes a dispute of principles.

However, GRCA officials view *Bison* as an invasive, human-introduced species to the Grand Canyon area because of an incorrect interpretation of an inconclusive report by Mead (2002) (Wakeling 2006; Larson et al. 2009). Yet, Mead (2002) explicitly states, "Most of the identifications [in natural history collections] indicate only 'Artiodactyla'… [and] that any deductions drawn from the known data… are at best **inconclusive**" (Mead 2002: 8 and 16; Mead 2004). Leading support to Mead's findings is the fact that only about 75 river miles or 27.1% of 277 total river miles of the Grand Canyon have been paleontologically and archaeologically surveyed in enough detail to draw informative conclusions of Pleistocene and Holocene natural history. Furthermore, including the tributaries of the Colorado River, which total over 800 river miles, less than 9.4% of the Grand Canyon's area has been surveyed in detail for paleontological and archaeological resources. Moreover, of the 4,927 square kilometers of Grand Canyon National Park (11th largest National Park), most of the scientific exploration is near the river and eastern portion of the park, excluding the western portion and most areas 1,000 meters above sea level in the park (Mead 2002; Mead pers. comm. 2013).

CHAPTER 2

METHODOLOGY

"For in the sciences the authority of thousands of opinions is not worth as much as one tiny spark of reason in an individual man. Besides, the modern observations deprive all former writers of any authority, since if they had seen what we see, they would have judged as we judge."

—Galileo Galilei

Framing the Project

Peer-reviewed publications documenting previously known bison and their associated ages from sites around the CP are necessary for this study. Even more critical are the undocumented and misidentified specimens from archaeological and paleontological collections at the Museum of Northern Arizona (MNA) and the GRCA collections. These previously undescribed specimens consist predominately of dung and skeletal remains from cave, rock shelter, and packrat midden localities; however, other specimens include isolated *Bison* elements that were misidentified. In select cases *Bison* specimens are directly radiocarbon dated (GRCA 69396 and MNA V8301). An accurate chronology is crucial to this study, as is a spatial assessment of the sites containing *Bison* spp. on the CP. Maps can illustrate a spatial pattern but temporal aspects are always difficult to incorporate without making a time series with a number of maps showing specific temporal ranges. Implications of findings are important for land and natural resource management and public policy decision makers.

Though establishing a paleontological and archaeological record for bison and their existence in the GGC and elsewhere on the CP since 11,700 years B.P. is the main goal of this project, specimens older than 11,700 years are included to be comprehensive. The last 11,700 years is a critical time range because it is the beginning of the Holocene when the climate was evolving into today's climate based on paleobotanical records (Betancourt 1990; McClaran and Van Devender 1995). However, major ecological and faunal turnover occurred about 11,700 years B.P. and, at the same time, the early Holocene climate was colder than today. In addition, the trophic interactions of large herbivores and their respective vegetative ecosystems need to be better understood to improve and inform management and conservation practices and policy (Fahnestock and Knapp 1994; McClaran and Van Devender 1995; Hunter 1996; Sanderson et al. 2008; Wolverton et al. 2011).

Methods

Paleozoological Review

Paleozoological refers to all fossil (paleontological), zooarcheological (archeological), and zoological (modern) data and faunal remains (Lyman and Cannon 2004), and these remains, collectively, with modern biology in the service of conservation is known as conservation paleobiology. Most of the descriptions provided herein are in paleontological terms, which follow the evolutionary development of bones as they adapt and morph over deep time. Previously known bison and their dates from literature were documented as well as previously unreported fossil and subfossil remains of dung, bone, and keratin from cave sites and archaeological sites on the CP and within the GGC.

Distinguishing *Bison* from *Bos.* To locate the specimens in the collections, I used the Grand Canyon National Park collections database, the Museum of Northern Arizona collections database, the Neotoma Paleoecology Database, and the Neogene Mammal Mapping Portal database to query for sites and specimens using keywords including Bison, Bos, cattle, taurus, buffalo, cow, large artiodactyl, ruminant, bovid, etc. The results gave specimen and site numbers that were investigated to check the identification and correct it if needed. Materials from other sites were examined in an effort to build a more complete dataset.

The identification of each specimen was then verified and corrected, if necessary, using Balkwill and Cumbaa (1992), which is an identification guide that improved upon Lawrence (1951b) and Olsen (1960) by providing 192 quantifiable osteological characters, as described in Lawrence (1951b) and Olsen (1960). Balkwill and Cumbaa (1992) take account of additional characters to include every postcranial element in the skeletons of 27 *Bison bison* and 16 *Bos taurus*. In attempt to capture the full extent of variation of *Bos taurus*, Balkwill and Cumbaa (1992) include several breeds of *Bos taurus* including Holstein, Ayrshire, Shorthorn, Longhorn, and Africander. Similarly, *Bison bison* is represented with the two subspecies, *Bison bison bison* (Plains bison) and *Bison bison athabascae* (Woods bison). In addition, to incorporate natural variation, Balkwill and Cumbaa (1992) include multiple ages and sexes of each species/breed.

Balkwill and Cumbaa (1992) statistically support each scored character in fractions of probable likelihood as well as qualitatively from ‘excellent’ to ‘probable.’ Throughout hundreds elemental and skeletal specimens I observed and reanalyzed, there were nearly 20 that were indeed *Bos* and not *Bison*; however, quite a few specimens turned out to be *Bison* and not *Bos*, though described as *Bos* in literature and databases. Chapter 3 contains the description of each available specimen I could revisit in the respective collections and the reason for reidentification, where necessary.

Museum and Site Visits and Data Collection

I visited the Denver Museum of Nature and Science (DMNS; Denver, CO), the University of Florida Museum of Natural History (FLMNH; Gainesville, FL), the Museum of Northern Arizona (MNA; Flagstaff, AZ), and the Grand Canyon National Park (GRCA; Grand Canyon Village, AZ). At each museum I went through the archaeological and paleontological collections looking for unidentified *Bison* skeletal elements. Specimens from DMNS and FLMNH did not pertain directly to the immediate study area yet provided morphological references and measurement data to create a baseline dataset.

To augment my results from the museum visits, I also obtained information about *Bison* spp. on the CP from online databases: Neotoma Paleoecology Database (NeotomaDB) and Neogene Mammal Mapping Portal (NeoMap). NeoMap is the combination of the Miocene Mammal Mapping Project (MIOMAP) and the Quaternary Faunal Mapping Project (FAUNMAP); in addition, FAUNMAP is a NeotomaDB constituent. I used both NeotomaDB and NeoMap to ensure the most thorough data. Although, it should be stated here that the 'element' of each animal found in the database is listed as 'bone/tooth,' which offers little to no osteological context.

Many of the location descriptions given in the respective collection databases, both online and in museums, are in the legal format of Township and Range, which creates a large polygon instead of a point and is imprecise when using point data for other site locations. For each site that was in legal description, the data were converted into the coordinate system by using a Township and Range (Clark 2014) overlay in Google Earth using decimal degrees. The location is approximate but more precise for spatial modelling and analysis.

Fossil Material and AMS Dates from New Sites

Some of the sites that are dated are older examples of conventional radiocarbon dating techniques compared to newer techniques of Accelerated Mass Spectrometry radiocarbon dates, typically used today. In addition, those sites that are directly dated on bone, dung, or plant material may not necessarily be representative of the *Bison* found at that site unless the specimen was confirmed *Bison*. This age discrepancy can be due to the unconformable properties of any given site's depositional nature. For example, if a *Bison* humerus is found in the same horizontal plane, as archaeologists usually excavate, as a dung bolus of *Mammut* (less than one meter away in the same horizontal plane), it does not necessarily mean that these 2 features are the same age. Careful lithological descriptions of the depositional layers (including secondary burrowing), as seen in caves and especially in open-air sites, is necessary. These attributes of age, stratigraphy, and identification combined introduce margins of error, especially when it comes to modeling analyses, but these attributes must be assumed accurate.

The same issues above are applied to archaeological sites where the site is dated using ceramic styles or lithic technology identification. Unless those sherds and lithics are found inside of the *Bison* bones, the dates used for each specimen of *Bison* may be in question, yet are assumed to be equivalent to the rest of the site. After all, we are not the first humans to take interest in collecting fossil specimens for trading pieces or curiosity.

Radiocarbon Analysis

The Accelerated Mass Spectrometry (AMS) radiocarbon dating methodology requires obtaining a minute physical sample (7 milligrams to 10 grams depending on material) (about the size of your small fingernail). In the case of the GRCA phalanx (GRCA 69396; which includes both compact and cortical bone), I arranged for a park official to use a rotary tool, e.g. – a

Dremel, to remove bone from the distal end of the phalanx. For the Navajo Nation Great Falls *Bison* rib (MNA V8301), I removed the proximal end of the rib (the articular head) for analysis. The laboratory used for AMS analyses is Beta Analytics (Miami, Florida). For other resources on radiocarbon dating visit Beta Analytic's radiocarbon dating website: http://www.radiocarbon.com/carbon-dating-bones.htm; also, Rafter Radiocarbon Laboratory has a YouTube video that shows how the process is completed: http://www.youtube.com/watch?v=-xKvq6VLe4s.

Temporal Definitions

Numerous time lines and chronologies have been created to relate North American climatic, cultural, and paleontological data. A compilation of selected chronologies is shown in Figure 4 to illustrate their similarities and differences.

Colorado Plateau Paleoclimate Review

Some aspects of North American climate have been well-studied on the CP, especially climatic shifts such as the Pleistocene - Holocene transition (Cole 1982; Martin 1987; Betancourt 1990; McClaran and Van Devender 1995; Anderson et al. 2000; Kropf et al. 2007; Coats et al. 2008; Cole 2010) and Holocene climatic variability (Lupo and Schmitt 1997; Broecker 2000; Finan et al. 2002; Shakun and Carlson 2010; Wanner et al. 2011). Paleoclimatic proxies such as packrat middens, fossil pollen, and lake sediment cores are used to reconstruct the paleoenvironment of the American Southwest (Betancourt 1990; Anderson et al. 2000; Broecker 2000; Shakun and Carlson 2010; Wanner et al. 2011). Temporal ranges (Figure 4) have been designated based on climatic events as follows: Oldest Dryas cold period (~18 to 14.7 ka (thousands of years ago)) (Shakun and Carlson 2010), Bølling/Allerød warm period (~14.7 to

12.9 ka) (Shakun and Carlson 2010), Younger Dryas cold event (~12.9 to 11.7 ka) (Shakun and Carlson 2010), Holocene (~11.7 ka to 1750 AD) (Broecker 2000), and the proposed Anthropocene (~1750 AD to Present) (Zalasiewicz et al. 2011; Barnosky and IB286 Working Group 2012).

North American Quaternary Chronologies

There are quite a few chronologies that are defined by specific metrics and cannot be integrated but all used here are necessary for relating each of my different sites that have *Bison* remains. The climatic regimes of the Pleistocene and Holocene are important to understand what events were climatically to force change upon an ecosystem and environment at a given time. Additionally, understand the mammalian faunal changes in response to these climatic pressures, and anthropogenically related pressures, is essential for understanding which animals may, or may not, occur together at a site, and it's these discrepancies that are red flags for further investigation, i.e. – *Bison* and *Bos* cannot co-occur before 1565 AD in North America because *Bos* wasn't introduced by Europeans yet. However, humans, Native Americans, were co-occurring with *Bison* for thousands of years in North America and they can be classified into cultural phases based on their technological or ideological evolution.

Bison dating to the Late Pleistocene (as used in this study; 11,700 to 160,000 years B.P.), although reported, are not well understood on the CP; and the Late Pleistocene and Holocene (less than 11,700 years B.P.) (Mead 2002). *Bison antiquus* of the Late Pleistocene and Early Holocene has been reported as recently as 4,300 years B.P. (McDonald and Lammers 2002); however, *B. bison* first appeared over 5,000 years B.P. as reported by McDonald (1981) illustrating a temporal overlap in species occurrence.

Portions of northern North America were covered repeatedly by advancing and retreating continental glaciers during the Pleistocene from 2.588 to 0.0117 Ma (Cohen et al. 2013). In addition, the montane west was inundated with alpine glaciers at the times of the continental glacial maximums. These alpine glaciers prohibited habitation of the highest elevations along the mountaintops above 3,500 m (Anderson et al. 2000). The Late Pleistocene includes the outdated but still pertinent Sangamonian interglacial and Wisconsinan glacial stages (Cohen et al. 2013).

<u>Land Mammal Ages.</u> The Pleistocene and Holocene are divided into biochronological units referred to as North American Land Mammal Ages based on faunal assemblage components. The Rancholabrean Land Mammal Age (LMA) is defined by the first appearance of *Bison* south of 55° N latitude and begins approximately 160,000 years B.P. based on a site in Jones Spring, Missouri (Bell et al. 2004). I use 160,000 years B.P. for this study. It should be noted that the earliest known first appearance of *Bison* has been reported in a stratum at American Falls, Idaho between the ages of 210,000 ±60,000 and 72,000 ±41,000 years B.P. (as discussed in Bell et al. 2004). Following the Rancholabrean LMA, the informally proposed "Santarosaean" LMA, which began 14,000 years B.P. and persisted until 1565 AD, is defined by the appearance of *Homo sapiens* south of 55° N latitude (Barnosky and IB286 Working Group 2012). Early "Santarosaean" LMA is characterized by the coexistence of *Homo sapiens* and now extinct Pleistocene megafauna and late "Santarosaean" LMA by the absence of both the now extinct megafauna and nonnative domestic animals.

Following the "Santarosaean" LMA, the informally proposed "Saintaugustinean" LMA is defined by the appearance of the reintroduced horse (*Equus ferus caballus*). This LMA is characterized by the widespread occurrence of introduced domestic species such as pigs (*Sus scrofa)*, cattle (*Bos taurus*), sheep (*Ovis aries*), rats (*Rattus* spp.), and goats (*Capra hircus*)

(Barnosky and IB286 Working Group 2012). *Bison* spp. occurs in both the "Santarosaean" and the "Saintaugustinean" LMAs. *Bison* continue to live and survive well into the 21st century, which is also informally and referred to as the "Anthropocene." This "age" is defined by the worldwide spread of geologic transformation caused by ground surface modification by *Homo sapiens* most likely beginning sometime around 1750 AD after the industrial revolution (Barnosky and IB286 Working Group 2012). Formal definitions and general acceptance of the "Santarosaean," "Saintaugustinean," and the "Anthropocene" are still under deliberation.

Pecos Classification. In addition to these mammal ages, archaeological stages have been created based on North American human cultures in the Southwest (Polyak and Asmerom 2001). The Pecos Classification (Figure 4) was used in this study because it is culturally specific to the CP region and the Southwestern United States. These latter subdivisions of the Pecos Classification are within contemporary times. Historical is defined by the use of written documentation that did not begin in the American Southwest until the Spanish Conquistador expeditions in 1540 AD. However, if ideas can be shared through graphic representations other than writing, such as in the form of ceramics designs and cave and rock paintings, these forms are dated to approximately 1200 AD (Reed 1952). Thus, for this study, 850 years B.P. to today is used for contemporary times, which includes the formal Historic, Prehistoric, and Protohistoric periods (as defined by Ahlstrom et al. 1993) to illustrate *Bison* nativity pre- and post contact of Europeans in the American Southwest using spatiotemporal maps. The site numbers in Figure 1 are referenced in Chapter 3: Results and are also referenced in Figure 19 with the corresponding colors of dots (and colored numbers in Figure 1 for when dots of different ages overlap). The dots are separated according to the more generalistic cultural stages given in Ahlstrom et al. (1993).

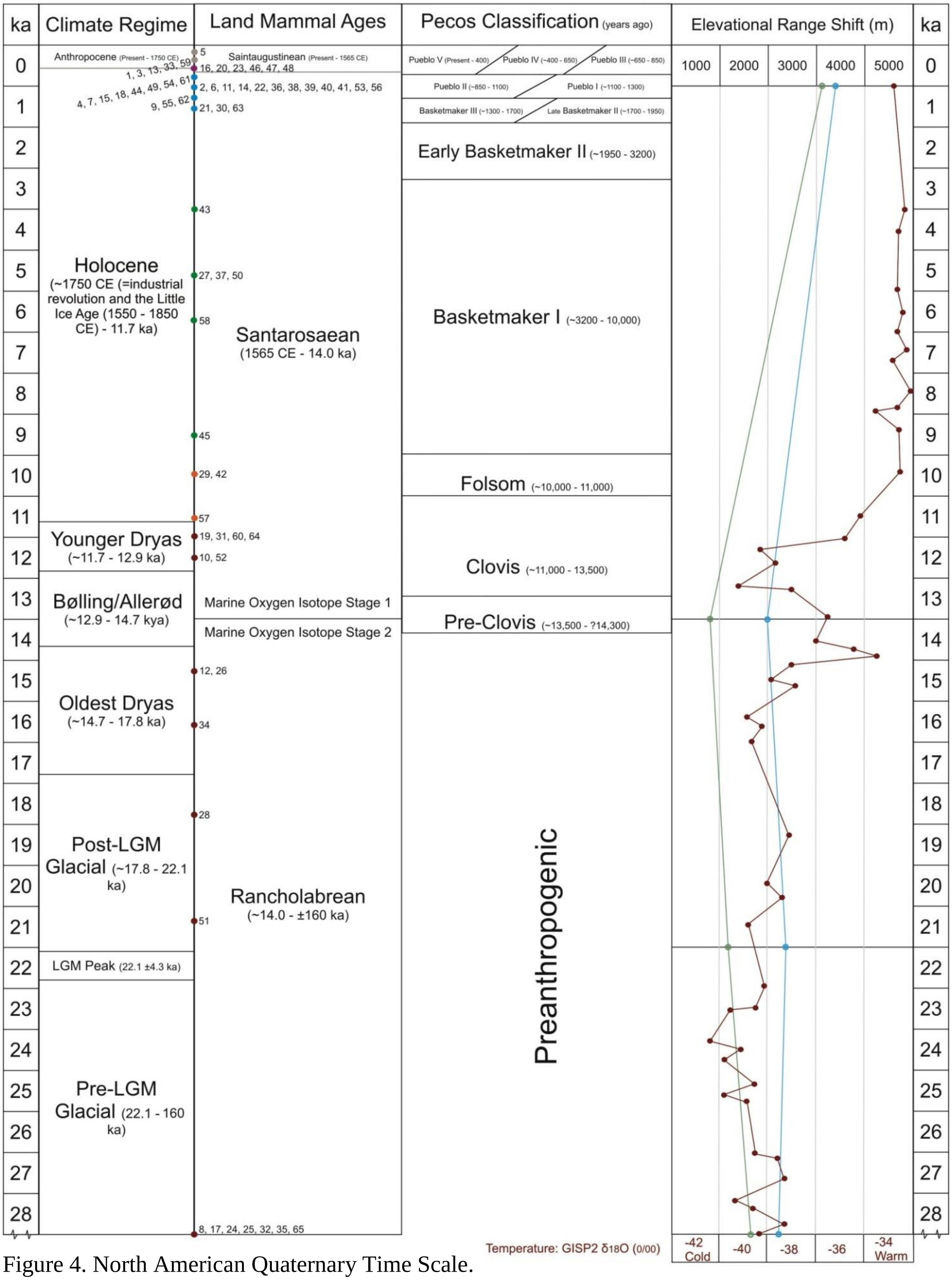


Figure 4. North American Quaternary Time Scale.

Figure 4. (continued) This time scale displays geological, paleontological (Land Mammal Ages: (Bell et al. 2004; Barnosky and IB286 Working Group 2012)), climatic (Climate Regime: (Zhao et al. 2005; Cohen et al. 2013)), and archaeological (Pecos Classification: (Polyak and Asmerom 2001)) units that are all important for relating *Bison* localities. The elevational range shift pertains to the pinyon-juniper (green line), fir and spruce (blue line) in relation to relative temperature change (burgundy line) in response to the relative temperature (GISP2). Data from: Marine Oxygen Isotope Stages (Anderson et al. 2000); Elevational Range Shift of fir/spruce (blue line) and pinyon/juniper (green line) from packrat middens (Cole 1985; Weng and Jackson 1999; Anderson et al. 2000); and Relative Temperature: GISP2 (Zhao et al. 2005). Abbreviations: ka = thousand years B.P.; AD, Anno Domini; m, meters.

Physiobiogeography of Grand Canyon and Colorado Plateau

Spatial Definitions

The expansive CP (129,107 mi^2; 334,385 km^2) is centered on the Four Corners region of the southwestern United States and covers eastern Utah, northern Arizona, western Colorado, and northwestern New Mexico. This immense physiographic province is bounded by the Rocky Mountains on the east, the Uinta Mountains on the north, the Basin and Range on the west, the Mogollon Rim on the south, and the Rio Grande Rift on the southeast. Average elevation on the CP is about 5,200 feet (1,585 m) with a range of 1,180 to 12,630 feet (360 - 3,850 m). Typically, the ecosystem is a high elevation desert with a few areas of alpine forests.

The climate of the CP is relatively arid—between 10 and 25 inches (25-63 cm) of precipitation annually, depending on elevation—which provides a fairly dry environment that enables preservation of dung, skeletal, and soft-tissues, including the keratinous hooves and horn sheaths, over tens of thousands of years (Jennings 1978; Mead 2002). Reflecting on this aridity, the most common bison remains on the CP is dung preserved in dry caves, rock shelters, and packrat middens (as discussed in (Mead 2002; USGS and Cole 2008)).

The GGC is defined as the land up to 16 km (10 mi) from GRCA boundaries (Figure 1), while the Grand Canyon is the actual physiographic incision of the Colorado River and its tributaries from the river up to the rim. Kaibab Plateau (Kaibab Uplift) refers to the northeastern portion of the Grand Canyon and is bound by the East and West Kaibab monoclines. This Plateau is also the location of the Kaibab National Forest (KNF) (Figure 1).

The most recent comprehensive analysis of *Bison* spp. was “North American bison: their classification and evolution” in which it illustrates the geographic “hole” of fossil bison records on the CP (McDonald 1981: 83, 92, and 103). However, geographically, there are well-documented occurrences of *Bison* spp. in the neighboring provinces of the Great Basin (Jennings 1978; McDonald 1981; Thompson and Mead 1982; Grayson and Livingston 1993; Van Vuren and Dietz 1993; Grayson 2006; Scott and Cox 2008), southern Rocky Mountains (McDonald 1981), Wyoming Basin (Jennings 1978; McDonald 1981), Sonora Desert (Agenbroad and Haynes 1975; Mead and Johnson 2004), Bonneville Basin (Jennings 1978; Madsen et al. 2001), Rio Grande Rift basin (Harris 1993), and the middle Rocky Mountains (McDonald 1981).

CHAPTER 3

RESULTS

τὰ ὄντα ἰέναι τε πάντα καὶ μένειν οὐδέν

Ta onta ienai te panta kai menein ouden

"All entities move and nothing remains still"

—Plato, Cratylus, Paragraph 401 section d line 5

Paleontology and Zooarcheology

The 2 hypotheses for my project are that: throughout the past 14,000 years, 1) *Bison* inhabited a large majority of the CP, and 2) *Bison* inhabited all suitable habitats of GRCA and KNF. My study adds to previous studies by Mead (2002), Larson et al. (2009), Reimondo (2012), and Huffer (2013). I provide, here, an interdisciplinary solution to the question of *Bison* nativity on the CP by creating maps that are holistic in terms of paleozoological attribute data (characteristics) for 65 *Bison* localities, with their respective ages.

As discussed in Chapter 2: Methods: Paleozoological Review: Distinguishing *Bison* from *Bos*, I use Balkwill and Cumbaa (1992) as my main skeletal identification source to differentiate the 2 genera. Most of the sites listed are presumed to have correct identifications as presented in the respective archival databases. Each site below is numbered by the Key ID from 1 through 65 (alphanumerically by site name), with the same Key ID number is used in Figure 1, Figure 19, and Figure. Minimum number of individuals (MNI) and number of individual specimens (NISP) will be reported where available.

Site Attributes

Each site below is numbered according to alphanumerical order; this is referred to as the Key ID number. The Key ID unites to the corresponding number displayed in the maps of the spatiotemporal analysis. Additionally, following the Key ID and name of the site, in parentheses, the latitude and longitude is given in decimal degrees rounded to the nearest hundredth due to sensitivity of the material. The age of each site is first given in the reported age by the literature or archival database, and then described how the date was obtained, and finally, converted to calendar years B.P. as a single mean number for spatiotemporal analysis. The calibration of the radiocarbon years is completed by using IntCal13 (Reimer et al. 2013) online software supplied by OxCal 4.2: https://c14.arch.ox.ac.uk/embed.php?File=oxcal.html. The averaged date of the calibrated age is assumed precise but should be understood to not be accurate. Pertinent peer reviewed reference and/or archival database for each site is provided.

Lastly, each site finishes with a discussion of each specimen found at the site. Here, I discuss the morphological characters distinguishing *Bison* from *Bos*. Additionally, where necessary, dialogue is provided discussing each site's age assignment and whether *Bos* or *Bison* is present. The site's age assignment is also subject to site mixing stratigraphically, taphonomically or by other means, thus making any sites where the age is an association with *Bison* remains a potential error.

Specimen Descriptions

1) 42SA8502 (N 38.27, W 109.86)

42SA8502, also referred to as The Neck in Canyonlands National Park, has 3 dates, AD 1235 – 1415; AD 1425 – 1655; AD 1485 – 1795 (Osborn et al. 1995). These dates are based on radiocarbon dating of charcoal. The average age of these yields an age of 435 calendar years B.P. used for my spatiotemporal analysis. Two cultural occupations are reported by Osborn et al. (1995) for this site and span the pre- and post contact of Europeans. However, Osborn et al. (1995) reported that *Bos*, *Bison*, and *Bos*/*Bison* are found at these sites. Mead (2002) provides a discussion on the issues with this site because of inadequate identification, especially dating near the contact of Europeans.

I did not view these specimens but reanalysis of faunal identifications is suggested. MNI of 2 based on left metacarpals are reported as *Bos*/*Bison* from a total of 19 NISP. MNI of 1 *Bison* based on NISP of 7. No other osteological descriptions available.

2) Ada Mesa (N 34.05, W 109.07)

Ada Mesa, also referred to as NA20657, dates to AD 600 – 700+ (Georgetown/San Francisco) and 1100+ (Tularosa). The dates are based on radiocarbon dates of Pit Houses that were burned, lithic technology, and ceramic styles (MNA archival database). The average age of these dates yield 1100 calendar years B.P. for my spatiotemporal analysis.

Recorded in the MNA archival database as *Bos* (from Lot.52) but my analysis changed the identification to *Bison* for the following reasons. Left distal radialulna (reported as distal left tibia of *Bos* (Lot.50)) but because the anterior margin of the facet for the scaphoid is indented (character 11; red line Figure 5A) my analysis suggests *Bison*, which occurs 24/27 times and in *Bos* only 2/14. Right distal femur, in lateral view (Figure 5B), (I corrected this from *Bos* in Lot.52) supracondylar fossa (character 14) is deep, suggesting *Bison*. This character occurs 27/28 times in *Bison* and in *Bos* 2/15.

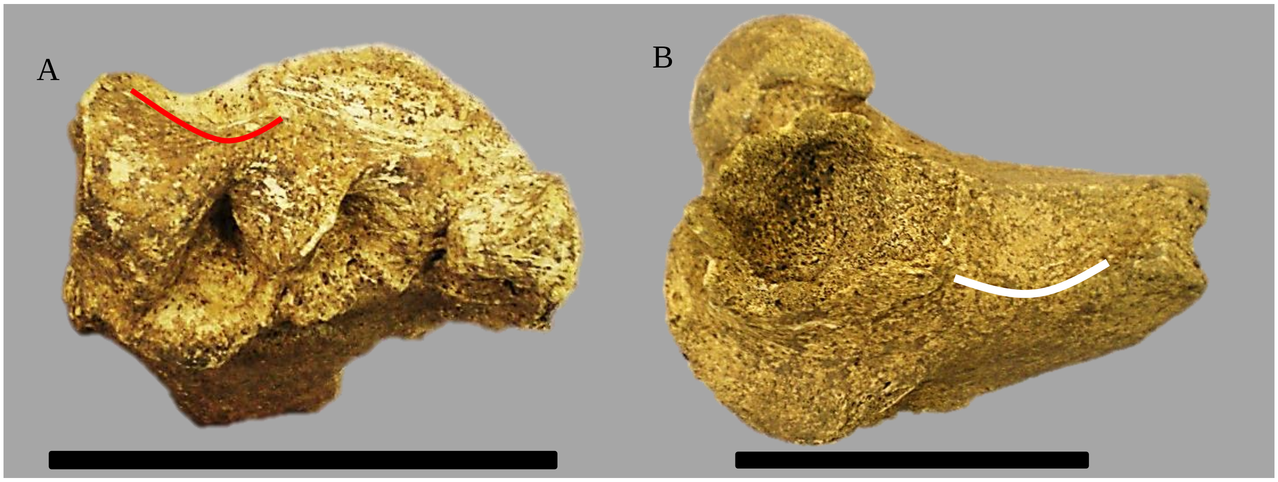


Figure 5. Ada Mesa A) *Bison* distal left radialulna (Lot.50) in distal view (anterior up) and B) *Bison* distal right femur (Lot.52) in lateral view (anterior down). A) Red line on the radialulna illustrates the indented anterior margin of the facet for the scaphoid articulation. B) White line on the femur illustrates the deep supracondylar fossa. Scales equal 10 cm.

3) Alcove Spring (N 37.54, W 111.25)

Alcove Spring, also referred to as 42SA8512, dates to AD 1345 – 1650 (Osborn et al. 1995). The dates are based on radiocarbon dates of charcoal associated with the site. The average age of these dates yields 453 calendar years B.P. for my spatiotemporal analysis. Two distinct cultural occupations are evident and this site may span the pre- and post contact of Europeans.

Bos/*Bison* MNI of 1 identified at this site based on NISP of 1 (no other osteological description available). Reanalysis of the material is suggested because I did not view this specimen.

4) Awatovi (N 35.75, W 110.25)

Awatovi, also referred to as 5910 in NeotomaDB and 2332 in NeoMap, dates to 250 – 1450 calendar years B.P. (Montgomery et al. 1949; Lawrence 1951; Agenbroad and Haynes

1975; NeotomaDB). The dates are based on radiocarbon dates (NeotomaDB). The average age of these dates yield 850 calendar years B.P. for my spatiotemporal analysis.

Lawrence (1951) states both *Bison bison* and *Bos taurus* as being identified from this site. I did not view these specimens for confirmation or comparison.

5) B:16:0461 (N 36.06, W 112.14)

B:16:0461 (this study of GRCA 69396) was dated. Beta 374436 sample produced a conventional radiocarbon age of 50 ±30 years B.P. (measured radiocarbon age of 100.5 ±0.4 pMC). This sample fits on the radiocarbon curve of IntCal13 (Figure 6) to between 1895 and 1905 AD (Cal B.P. 55 to 45) in the 1 Sigma calibration (68% probability) of Post AD 1950 (Post BP 0). The 2 Sigma calibration results in multiple dates: Cal AD 1695 to 1725 (Cal BP 255 to 225); Cal AD 1815 to 1835 (Cal BP 135 to 115); Cal AD 1880 to 1915 (Cal BP 70 to 35); Post AD 1950 (Post BP 0). Based on the description of the locality (AZ B:16:0461) in the GRCA computer database, this was a surface collection from the Mather Campground area, the age could be any of these choices of potential ages. I suggest that the most parsimonious date is would be the 1895 to 1905 AD (Cal B.P. 55 to 45) date. Measure of 13C/12C resulted in -19.4‰ and 15N/14N resulted +5.2‰. The average age of these dates yield 126 calendar years B.P. for my spatiotemporal analysis. This site had not previously been reported and this specimen was not identified in the archival database of GRCA.

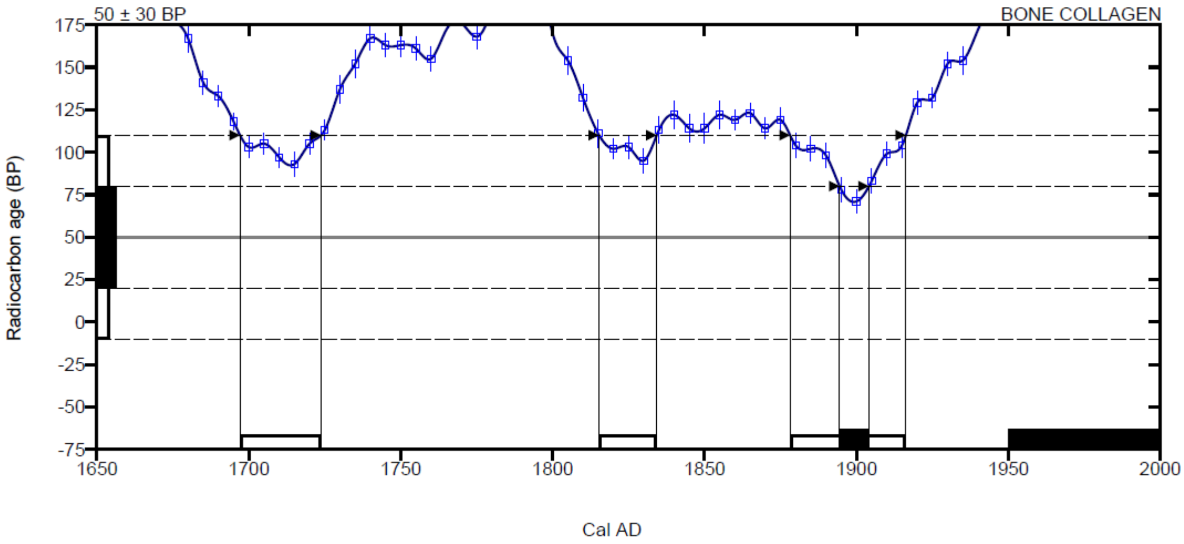


Figure 6. Radiocarbon years calibration chart for GRCA 69396 to calendar AD. Chart information supplied by Beta Analytic and calibration based on Reimer et al. (2013) IntCal13.

Proximal phalanx (lateral half; GRCA 69396). Proximal phalanx distal two-thirds of the lateral margin is curved (character 1; red line in Figure 7A) suggests *Bison* that occurs 10/24 times and in *Bos* 1/14.

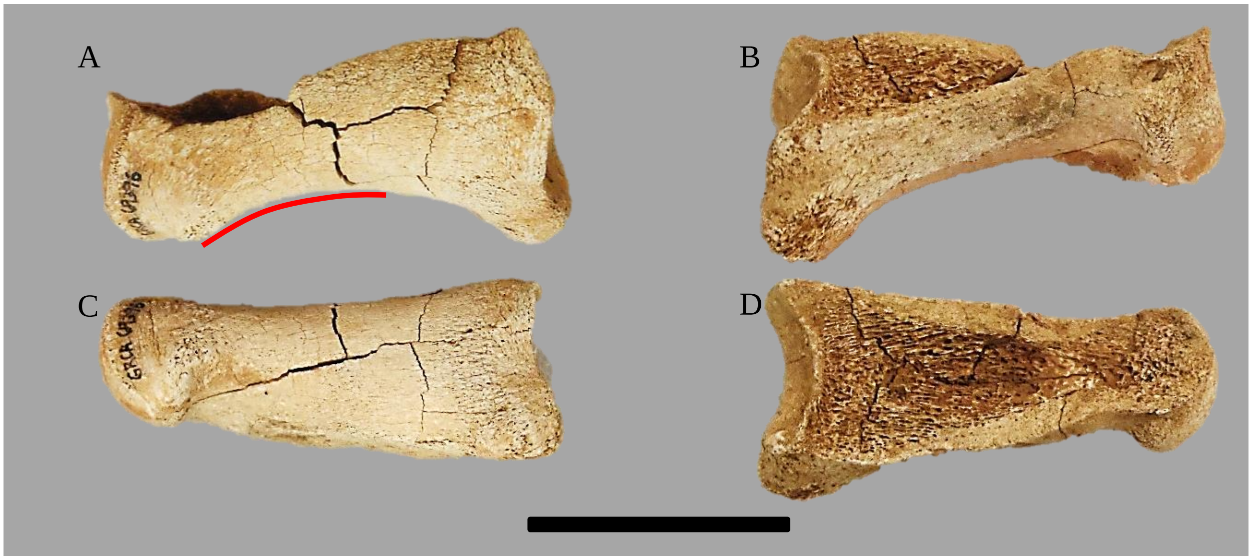


Figure 7. B:16:0461 proximal *Bison* phalanx (GRCA 69396) in A) dorsal view (distal end to left), B) plantar view (distal end to right), C) lateral view (distal end to left), D) medial view (distal end to right). Red line in A illustrates lateral margin curvature. Scale equals 5 cm.

6) B:16:105 (N 36.05, W 112.14)

B:16:105 dates to 927 calendar years B.P. (Downum et al. 2011). The dates are based on radiocarbon dates of charcoal (1000 years B.P.) and ceramic styles. The average age of this date yields 927 calendar years B.P. for my spatiotemporal analysis. There are reported *Bison* fatty lipids on ceramic pots (Downum et al. 2011). I did not view these samples.

7) Badger Spring (N 36.50, W 110.83)

Badger Spring, also referred to as MNA.Loc.112-0, the Pleistocene (MNA archival database; Hayes and Lancaster 1975; McDonald 1981; Mead et al. 2005). The reported Pleistocene age of this site and presence of *Bison antiquus* suggests that the age of the site is no younger than 11,700 years B.P. and no more than 160,000 years B.P. based on the description of the Holocene and Rancholabrean Land Mammal Age (Bell et al. 2004; Cohen et al. 2013). For my spatiotemporal analysis of this locality, I have created an age point of 14,000 calendar years B.P.

Partial skull calvarium (Figure 8; MNA.V.90) of *Bison antiquus*, as reported in McDonald (1981), archived in the MNA collections. I agree based on the metrics provided by Skinner and Kaisen (1947) and McDonald (1981) that the identification is *Bison*.

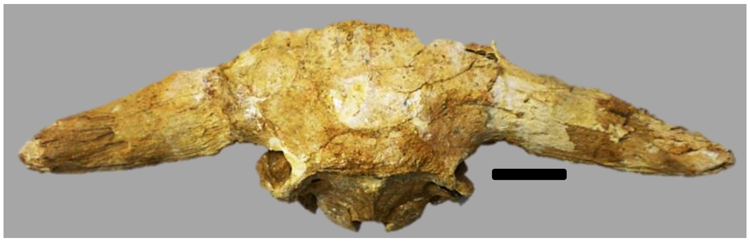


Figure 8. Badger Spring partial *Bison antiquus* calvarium in dorsal view (anterior up). Scale equals 10 cm.

8) Battleship Rock (N 36.08, W 112.14)

Battleship Rock dates to the Pleistocene (GRCA archival database; Mead pers. comm. 2014). The reported Pleistocene age of this site and presence of *Bison antiquus* suggests that the age of the site is no younger than 11,700 years B.P. and no more than 160,000 years B.P. based on the description of the Holocene and the Rancholabrean Land Mammal Age (Bell et al. 2004; Cohen et al. 2013). For my spatiotemporal analysis of this locality, I have created an age point of 14,000 calendar years B.P.

Bison teeth from the nest of Pleistocene aged *Gymnogyps* (California condor) nest, which, today, have a home range in the Grand Canyon of 160.9 km for carrion (AZGFD 2013). Though difficult to differentiate *Bison* teeth from *Bos* teeth, the age suggests *Bison* sp. as the most parsimonious.

9) Bear Ruin (N 34.36, W 110.02)

Bear Ruin, also referred to as AZ P:16:1, dates to 550 – 700 calendar years B.P. (Haury 1940; Agenbroad and Haynes 1975; Lightfoot and Feinman 1982). The dates are based on ceramic styles. The average age of these dates yield 1325 calendar years B.P. for my spatiotemporal analysis.

This site is listed to have *Bison bison* with no osteological context, it is assumed to be accurate and I did not view these specimens.

10) Bechan Cave (N 38.00, W 111.00)

Bechan Cave, also referred to as NAU QSP Site 872 and GLCA Accession 81, dates to 13,590 ±369 calendar years B.P. and 16,289 ±854 calendar years B.P. (Mead and Agenbroad 1989; Mead and Agenbroad 1992; Kropf et al. 2007). The dates are based on radiocarbon dates of 11,670 ±300 and 13,505 ±580 on the *Mammuthus* dung layer containing *Bison* dung. The average age of these dates yield 15,182 calendar years B.P. for my spatiotemporal analysis.

Dung morphology identified as *Bison* sp. (Mead and Agenbroad 1989; Mead and Agenbroad 1992) found in same stratum with *Euceratherium* and *Mammuthus*. I did not review these specimens.

11) Bessie Bottom Site (N 41.02, W 110.87)

Bessie Bottom Site, also referred to as 48UT1186 and 4810 in NeotomaDB, dates to 1106 calendar years B.P. from cultural component 1 and 859 calendar years B.P. from cultural component 2 (McKern 1988; NeotomaDB). The dates are based on radiocarbon dates from unspecified remains from cultural component 1 (1170 ±60 years B.P.) and unspecified remains from cultural component 2 (910 ±80 years B.P.) (NeotomaDB). The average age of these dates yield 985 calendar years B.P. for my spatiotemporal analysis.

Bison bison from cultural component 1 has a NISP of 991 and *Bison bison* a NISP of 28 (MNI of 1) in cultural component 2. I did not view these specimens.

12) BF Alcove (N 37.34, W 111.00)

This site came up in my search (Santucci et al. 2001) as having *Bison* but does not contain *Bison* according to Mead and Agenbroad (Mead and Agenbroad 1992) and Mead (2013 pers. comm.). This site was not used in my geospatial analysis for migration and seasonal range.

13) Bison Alcove (N 38.73, W 109.50)

Bison Alcove, also referred to as 42GR538 (ARCH 115), MNA Loc.9144, 6290 in NeotomaDB, and 2958 in NeoMap. Bison Alcove dates to AD 1405 – 1420 and AD 1535 – 1605

(Mead et al. 1991; Mead 2002; NeotomaDB; NeoMap). The dates are based on radiocarbon dates of 355 ±60 from a *Bison* keratinous hoof and 405 ±65 from a *Bison* horn sheath (NeotomaDB). The average age of these dates yield 445 calendar years B.P. for my spatiotemporal analysis.

One horn sheath, 2 vertebral centrum plates, a proximal ulna, 1st phalanx, three 2nd phalanges, 3 unguals, and 1 keratinous hoof as described (Mead et al. 1991).

14) Black Mesa (N 36.37, W 110.37)

Black Mesa, also referred to as D:11:2062, D:7:0713, and 6010 in NeotomaDB, dates to 885 ±72 calendar years B.P. for D:11:2062 and 1673 ±117 calendar years B.P. (Leonard 1989; NeotomaDB). The dates are based on radiocarbon dates of unspecified remains (920 – 1050 years B.P.) in site D:11:2062 and of unspecified remains (1650 – 1850 years B.P.) in site D:7:0713 (NeotomaDB). The average age of these dates yield 1302 calendar years B.P. for my spatiotemporal analysis.

Reported as *Bos* but I identified this as *Bison*. Both sites list *Bos taurus* as the faunal component of the assemblage; however, both sites (MNI of 1 in each) are too old by no less than approximately 430 years before *Bos taurus* was introduced to North America. I did not view these specimens. Possible explanations include: 1) these specimens are *Bison bison*, 2) the dates could be erroneous, or 3) the initial identification of *Bos* may have also been misleading and may in actuality be an elk or similar artiodactyl. At this time, it would seem most parsimonious that the specimen is *Bison bison*.

15) Canyon Diablo Dam (N 35.02, W 111.00)

Canyon Diablo Dam, also referred to as NA8793, dates to 850 – 1100 calendar years B.P. (MNA archival database). The dates are based on Pueblo II and possibly Kayenta ceramic styles

(MNA archival database). The average age of these dates yield 975 calendar years B.P. for my spatiotemporal analysis.

From Lot.1, a right lateral second phalanx and a right naviculocuboid. The right naviculocuboid Figure 9) has a continuous surface connecting the distal articular surface for the astragalus and that of the meso-ectocuneiform (character 1) which occurs in *Bison* 19/23 times and in *Bos* 7/12. The articular surface for the astragalus is rounded in an anteroposterior direction (character 2) that occurs in *Bison* 18/23 times and in *Bos* 2/13. The ventromedial portion of the posterior surface is intermediately scooped out on so that the medial edge is intermediately defined (character 3) and occurs in *Bison* 3/22 times and in *Bos* 0/13. My assessment is that the material is *Bison*.

Figure 9. Canyon Diablo Dam *Bison* right naviculocuboid (#7136) in distal view (anterior down). Arrow indicates the continuous surface connecting the distal articular surface for the astragalus and that of the meso-ectocuneiform. Scale equals 5 cm.

<u>16) CC:1:133 (N 36.81, W 111.63)</u>

CC:1:133 (ASM), also referred to as Smith Tank Site, dates to AD 1275 (Woodson 2007; NeoMap) that places it into Pueblo III of the Pecos Classification that ranges 650 to 850 calendar years ago. The date is based on ceramic styles (Woodson 2007; NeoMap). The average age of these Pueblo III ranges yield 750 calendar years B.P. for my spatiotemporal analysis.

Bison listed in NeoMap database. I did not view these specimens.

17) Charley Day Spring (N 36.51, W 110.76)

Charley Day Spring is also referred to as Charley Day Well, NA1898, and MNA Loc.149-1. Charley Day Spring dates to the Pleistocene based on the co-occurrence of *Bison* with *Mammuthus*, *Equus*, and *Camelops* (Lindsay and Tessman 1974; Agenbroad and Haynes 1975; MNA archival database) that places it into Rancholabrean LMA (160,000 to 14,000 calendar years B.P.). For my spatiotemporal analysis of this locality, I have created an age point of 14,000 calendar years B.P.

Bison antiquus (as reported in MNA archival database) teeth (molars, premolars, incisors). The molars are most certainly of Bovini tribe affinity because of the presence of the pronounced ectostylids and entostyles; the only taxon of Bovini found in the western hemisphere during the Rancholabrean is *Bison*. Based on the Pleistocene-aged nature of the site I concur with the taxonomic classification of *Bison antiquus* as Bovini teeth are difficult to differentiate.

18) Cottonwood Seep Spring (N 35.02, W 109.54)

Cottonwood Seep Spring, also referred to as NA14674, dates to Pueblo II (MNA archival database) that places it into the Pecos Classification and ranges from 850 to 1100 calendar years ago. The date is based on Anasazi ceramic styles (MNA archival database). The average age of the Pueblo II range yields 975 calendar years B.P. for my spatiotemporal analysis.

Reported as *Bos taurus* thoracic vertebra (MNA archival database) but my assessment identifies it is as a *Bison* 7th cervical vertebra (Figure 10) (in Lot.955 as labeled on the bag; however, in the MNA archives it is labeled as Lot.155), and a *Bison* worked scapula tool was also collected from here (I did not view the scapula (in GSQS6-77) as it was checked out of the MNA archeology collections for a specimen research loan). It is interesting that from the same site, the identification of the worked scapula is *Bison*, whereas the vertebra is identified as *Bos taurus*.

The 7th cervical vertebra has an acute angle of the transverse process to the prezygapophysis (character 17) that occurs in *Bison* 24/24 times and in *Bos* 0/12.

Figure 10. Cottonwood Seep Spring *Bison* 7th cervical vertebra in anterior view (dorsal up). Red line illustrates the acute angle of the transverse process to the prezygapophysis. Scale equals 5 cm.

19) Cowboy Cave (N 38.32, W 110.20)

Cowboy Cave is also referred to as 45WN420, 9761 in NeotomaDB, and 2048 in NeoMap. Cowboy Cave dates to 12,917 ±152 calendar years B.P. and 15,565 ±707 calendar years B.P. (Hansen 1980; Mead and Agenbroad 1989; Mead and Agenbroad 1992; NeotomaDB; NeoMap). The dates are based on radiocarbon dates of 11,020 ±180 and 13,040 ±440, respectively, on *Bison* dung. The average age of these dates yield 14,519 calendar years B.P. for my spatiotemporal analysis.

Dung morphology indicates an identification of *Bison* sp. as reported by Mead and Agenbroad (Mead and Agenbroad 1992). I did not view these specimens.

20) Coyote Creek (N 34.17, W 109.15)

Coyote Creek, also referred to as NA14064, dates to the Tularosa phase of the Anasazi culture (MNA archival database) which places it into Pueblo III of the Pecos Classification which ranges 650 to 850 calendar years ago. The date is based on lithic technology and building foundation style (MNA archival database). The average age of these Pueblo III ranges yield 750 calendar years B.P. for my spatiotemporal analysis.

Phalanx, metacarpal, cut marked magnum, charred and cut-marked right astragalus, human butchered right naviculocuboid, vertebra, and mandible fragment with teeth. The right naviculocuboid (Figure 11) has a continuous surface connecting the distal articular surface for the metatarsal and that of the fused second and meso-ectocuneiform (character 1) that occurs in *Bison* 19/23 times and in *Bos* 7/12. The articular surface for the metatarsal is rounded in an anteroposterior direction (character 2) which occurs in *Bison* 18/23 times and in *Bos* 2/13. The ventromedial portion of the posterior surface is not scooped out so that the medial edge barely stands out in a poorly defined ridge (character 3) which occurs in *Bison* 14/22 times and in *Bos* 0/13. The most parsimonious taxon as identified here is *Bison*.

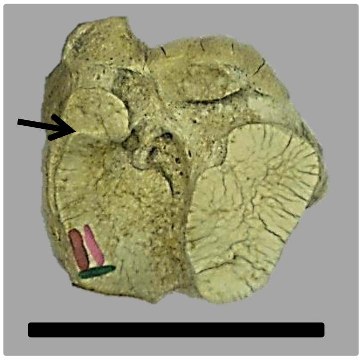


Figure 11. Coyote Creek *Bison* right naviculocuboid in distal view (anterior down). Black arrow indicates the continuous surface connecting the distal articular surface for the metatarsal and that of the fused second and meso-ectocuneiform. MNA collection personnel applied painted lines to indicate the butcher marks. Scale equals 5 cm.

21) Dust Devil Cave (N 37.09, W 111.13)

Dust Devil Cave, also referred to as NA7613 and MNA.UT:V:13:160, dates to the Kayenta phase (MNA archival database) which places it into Pueblo II of the Pecos Classification which ranges 850 to 1100 calendar years ago. The date is based on ceramic styles (MNA archival database). The average age of the Pueblo II range yields 480 calendar years B.P. for my spatiotemporal analysis.

Distal phalanx. The plantar margin is straight (character 1) that occurs in *Bison* 11/13 times and in *Bos* 5/14. The inner margin is concave (character 3) that occurs in *Bison* 10/13 times and in *Bos* 1/14. The dorsoposterior corner broadly rounded (character 4) that occurs in *Bison* 10/13 times and in *Bos* 1/14. The most parsimonious taxon as identified here is *Bison*.

22) Ephraim (N 39.25, W 111.50)

Ephraim, also referred to as Witch's Knoll and 7683 in NeotomaDB, dates to 664 ±6 calendar years B.P. and 1020 ±22 calendar years B.P. (Gillin and Allen 1941; NeotomaDB). The date is based on radiocarbon dates on unspecified remains of 690 years B.P. and 1130 years B.P.

(Gillin and Allen 1941; NeotomaDB). The average age of these calibrated dates yield 850 calendar years B.P. for my spatiotemporal analysis.

Bison bison listed in NeotomaDB without osteological description; I did not view this specimen.

23) Fort Davy Crockett (N 40.75, W 108.75)

Fort Davy Crockett, also referred to as 5MF605, 5210 in NeotomaDB, and 1165 in NeoMap, dates to 50 ±1 calendar years B.P. and 927 ±3 calendar years B.P. (Sharrock 1966; Walker 1983; NeotomaDB; NeoMap). The date is based on radiocarbon dates on unspecified remains dating to 50 years B.P. and 1000 years B.P. (NeotomaDB). The average age of these dates yield 490 calendar years B.P. for my spatiotemporal analysis.

Unspecified *Bison bison* remains with evidence of human butchering modifications (NeotomaDB) with a MNI of 5; I did not view these specimens.

24) Grand Falls (N 35.92, W 111.53)

Grand Falls, also referred to as MNA V8301 Loc. 1104 was dated. Beta 374435 sample produced a conventional radiocarbon age of 50 ±30 years B.P. (measured radiocarbon age of 102.4 ±0.4 pMC). This sample fits on the radiocarbon curve of INTCAL13 (Figure 12) to between 1895 and 1905 AD (Cal B.P. 55 to 45) in the 1 Sigma calibration (68% probability) of Post AD 1950 (Post BP 0). The 2 Sigma calibration results in multiple dates: Cal AD 1695 to 1725 (Cal BP 255 to 225); Cal AD 1815 to 1835 (Cal BP 135 to 115); Cal AD 1880 to 1915 (Cal BP 70 to 35); Post AD 1950 (Post BP 0). Based on the description of the locality (MNA V8301 Loc. 1104) in the MNA computer database, this was an arroyo collection from near the Little Colorado River; the age could be any of these choices of potential ages. I suggest that the most parsimonious date is would be the 1895 to 1905 AD (Cal B.P. 55 to 45) date. Measure of 13C/12C resulted in -19.4‰ and 15N/14N resulted +5.2‰. The average age of these dates yield 126 calendar years B.P. for my spatiotemporal analysis. This site had not previously been reported.

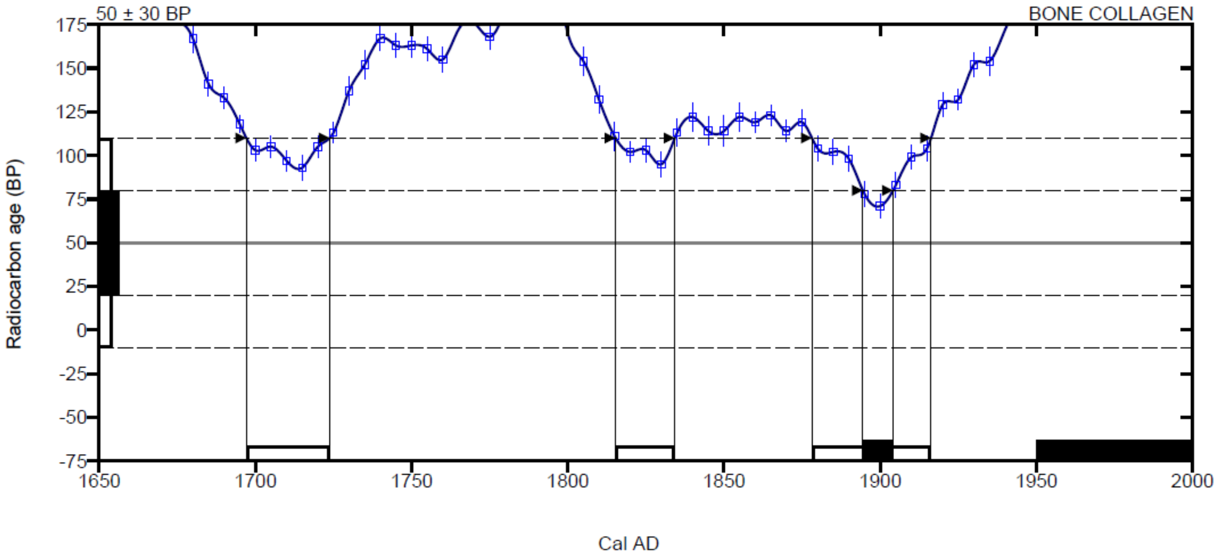


Figure 12. Radiocarbon years calibration chart for MNA.V8301 Loc.1104 to calendar AD. Chart information supplied by Beta Analytic and calibration based on Reimer et al. (2013) IntCal13.

One mostly complete individual (postcranial) and one-half complete individual (postcranial). Both individuals' podial elements were glued together. Both individuals are also juvenile and were deposited 45 feet apart in the same arroyo. Here I only describe the naviculocuboid and astragalus for identification purposes because these elements are unglued, reliable elements, and all of the elements were found as an articulated specimen. The ventromedial portion of the posterior surface of the naviculocuboid is not scooped out so that the medial edge barely stands out in a poorly defined ridge (character 3) that occurs in *Bison* 14/22 times and in *Bos* 0/13. The astragalus medial tubercle (character 3) is on a level with or above the line drawn across the proximal margin of the distal trochlea that occurs in *Bison* 27/27 times and in *Bos* 4/15. The astragalus (Figure 13) posterior surface is excavated (character 1) and extends as far as the lateral margin that occurs in *Bison* 23 /26 times, and in *Bos* 2/15. The most parsimonious taxon as identified here is *Bison*.

Figure 13. Grand Falls *Bison* right astragalus in posterior view (proximal end up). Black arrow indicates the excavated surface that extends as far as the lateral margin. Scale equals 5 cm.

<u>25) Gray Water Wash (N 36.82, W 108.94)</u>

Gray Water Wash, also referred to as MNA Loc.358-0, dates to the Pleistocene (MNA archival database) which places it into Rancholabrean Land Mammal Age (160,000 to 14,000 calendar years B.P.). The date is based on the stratigraphy and conclusions of the initial investigators. For my spatiotemporal analysis of this locality, I have created an age point of 14,000 calendar years B.P.

Three tibia, two distal metapodials, and a radialulna are present and mostly in poor preservation. Metapodials, the metacarpals and metatarsals, are difficult to distinguish from each other, often requiring the proximal end for elemental identification but taxonomic identification can be acquired with the distal end. One of the distal metapodials, as in Figure 14, illustrates a swelling above the distal condyles (character 2) that occurs in *Bison* 25/25 times and in *Bos* 3/13 for metacarpals; 24/27 times in *Bison* and 2/14 times in *Bos* for the metatarsal. My identification assessment of these elements results in *Bison*.

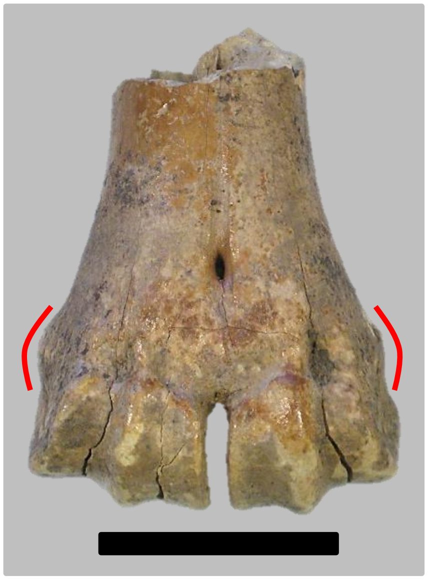


Figure 14. Gray Water Wash *Bison* distal metapodial in anterior view (plantar/distal end down). Red lines illustrates swelling above the distal condyles. Scale equals 5 cm.

26) Grobot Grotto (N 37.40, W 111.00)

Grobot Grotto, also referred to as NAU QSP Site 878 and GLCA Accession 82, dates to 18,528 ±137 calendar years B.P. and 33,540 ±2836 calendar years B.P. (Mead and Agenbroad 1989; Mead and Agenbroad 1992; Withers and Mead 1993). The dates are based on radiocarbon dates of 15,270 ±120 and 28,290 ±2100 on *Bison* dung. The average age of these dates yield 27,384 calendar years B.P. for my spatiotemporal analysis.

Dung morphology identification of *Bison* sp. (Mead and Agenbroad 1989; Mead and Agenbroad 1992); I did not view these specimens.

27) Hamblin Springs (N 37.53, W 113.60)

Hamblin Springs, also referred to as 6329 in NeoMap, dates to the Holocene (NeoMap) that ranges from today to 11,700 calendar years B.P. The date is based on the unsubstantiated evidence of spring alluvium and co-occurrence with *Thomomys* sp. by the initial investigator. The average age of the Holocene range yields 5850 calendar years B.P. for my spatiotemporal analysis.

Bison sp. listed in the NeoMap database and I did not view these specimens.

28) Hooper's Hollow (N 37.34, W 111.01)

Hooper’s Hollow, also referred to as NAU QSP Site 873 and GLCA Accession 82, dates to 22,783 ±405 calendar years B.P. (Mead and Agenbroad 1989; Mead and Agenbroad 1992; Withers and Mead 1993). The dates are based on radiocarbon dates of 18,840 ±350 on *Bison* dung. The average age of this date yields 22,783 calendar years B.P. for my spatiotemporal analysis.

Dung morphology identification of *Bison* sp. (Mead and Agenbroad 1989; Mead and Agenbroad 1992) and I did not view these specimens.

29) Huntington Reservoir Sinkhole (N 39.50, W 111.25)

Huntington Reservoir Sinkhole, also referred to as 5735 in NeotomaDB and 1953 in NeoMap, dates to 12,668 ±296 calendar years B.P. (Miller 1987; Gillette and Madsen 1992; NeotomaDB; NeoMap). The dates are based on radiocarbon dates of 10,800 ±250 on *Mammut* bone amino. The average age of this date yields 12,668 calendar years B.P. for my spatiotemporal analysis.

Bison sp. with 1 MNI of a weathered bone/tooth as listed in NeoMap database and I did not view this specimen.

30) Needles and Maze Districts (N 38.22, W 109.86)

Needles and Maze Districts of Canyonlands (CANY) National Park dates to AD 900 – 1100 (Mead 2002; Malotki and Wallace 2011) that places it into Pueblo II of the Pecos Classification which ranges 850 to 1100 calendar years ago. The date is based on carving styles (Malotki and Wallace 2011). The average age of these Pueblo II ranges yield 975 calendar years B.P. for my spatiotemporal analysis.

Bovid style depiction using recurved horns with a distinct dorsal hump as seen in Figure 15 (white boxes). However, medicine men or shaman, ritually use bison heads (usually just the top of the head with the horns) as headgear for spiritual purposes. Other pictographs are found in Horseshoe Canyon in CANY, depicting bison as in Figure 16. However, relicts such as these should be interpreted with caution because thoughts of people can travel large distances thus suggesting that drawings *Bison* may actually not indicate that *Bison* are from the immediate location of the drawing. It may simply represent a storyboard and the drawings are used as visual enhancements. It is assumed here, though, that the *Bison* indicate they were of close proximity.

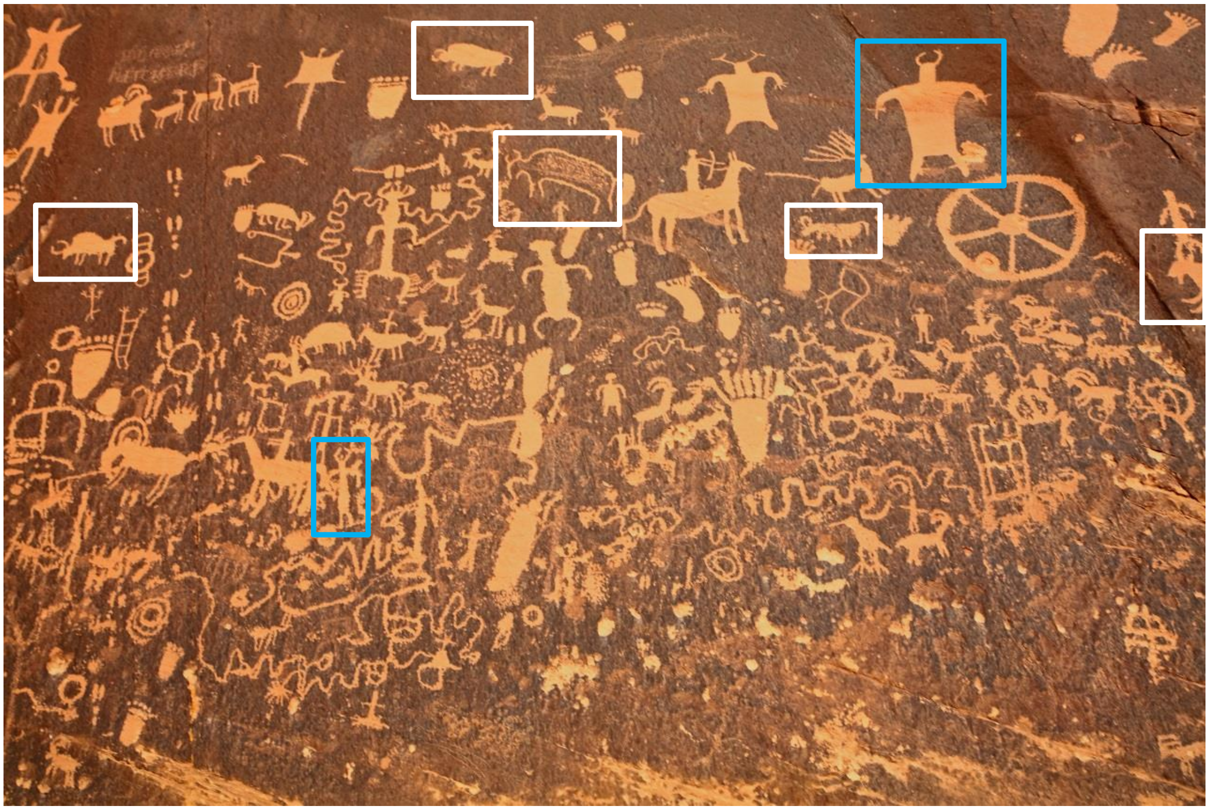


Figure 15. Newspaper Rock, Needles District, Canyonlands National Park. White boxes indicate bison-like forms and light blue boxes indicate bison-like headgear for shaman spiritual purposes (identification by Malotki and Wallace 2011; photograph from Wikimedia Commons).

Figure 16. Native American with bow and bison pictograph, Horseshoe Canyon, Maze District, Canyonlands National Park (identification by Malotki and Wallace 2011; photograph by Martin 2013).

31) Jim Walter's Cave (N 38.32, W 110.20)

Jim Walter’s Cave is adjacent to Cowboy Cave. The dates of Jim Walter’s Cave here are assumed to be associated with Cowboy from the close proximity that dates to 12,917 ±152 calendar years B.P. and 15,565 ±707 calendar years B.P. (Hansen 1980; Mead and Agenbroad 1992; NeotomaDB; NeoMap). The dates are based on radiocarbon dates of 11,020 ±180 and 13,040 ±440, respectively, on *Bison* dung in Cowboy Cave. The average age of these dates yield 14,519 calendar years B.P. for my spatiotemporal analysis.

First medial right rear proximal phalanx (ETVP 5980), right scaphoid (ETVP 5983), and right jugal (ETVP 5982). The anteroventral lunar articular facet of the scaphoid (Figure 17A) extends to the anterior margin (character 4) that occurs 18/21 times in *Bison* and 3/12 in *Bos*. Additionally, the right scaphoid (Figure 17B) posterior margin forms a continuous curve in medial view (character 3) that occurs in *Bison* 21/23 times and in *Bos* 3/12. The most parsimonious taxon as identified here is *Bison*.

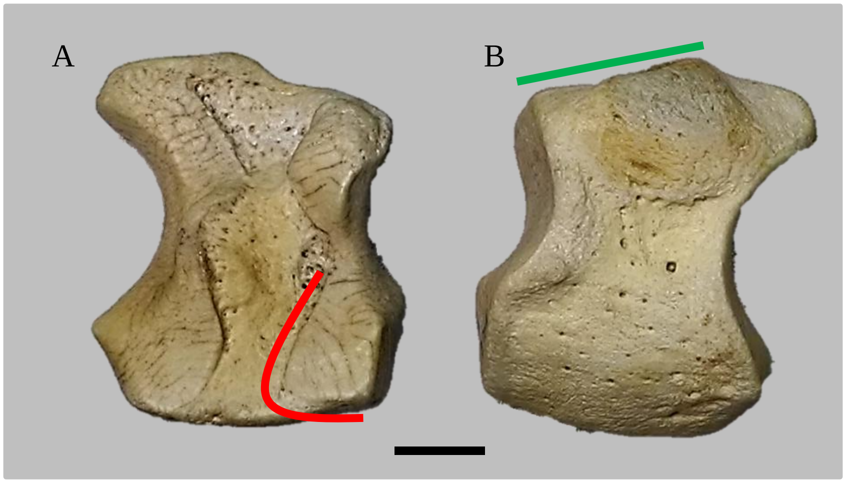


Figure 17. Jim Walter’s Cave *Bison* right scaphoid in A) lateral view and in B) medial view (anterior down). The red line (in A) illustrates lunar articular facet extending to the anterior margin, and the green line (in B) illustrates the continuous curve of the posterior margin. Scale equals 1 cm.

32) Keams Canyon (N 35.81, W 110.20)

Keams Canyon dates to the Pleistocene (Hay 1927; Lindsay and Tessman 1974; Agenbroad and Haynes 1975) which places it into Rancholabrean Land Mammal Age (160,000 to 14,000 calendar years B.P.). For my spatiotemporal analysis of this locality, I have created an age point of 14,000 calendar years B.P.

This site is listed (Hay 1927; Lindsay and Tessman 1974; Agenbroad and Haynes 1975) to have *Bison* sp. without osteological context, it is assumed accurate; I did not view these specimens.

33) Las Colinas (N 33.43, W 111.98)

Las Colinas dates to the Hohokam culture (Johnson 1974; Agenbroad and Haynes 1975; Teague and Deaver 1989) that places it into Pueblo IV of the Pecos Classification that ranges from 400 to 650 calendar years ago. The average age of these Pueblo IV ranges yield 525 calendar years B.P. for my spatiotemporal analysis.

This site is listed (Johnson 1974; Agenbroad and Haynes 1975; Teague and Deaver 1989) to have *Bison bison* without osteological context, it is assumed accurate; I did not view these specimens.

34) Mammoth Alcove (N 37.33, W 110.99)

Mammoth Alcove, also referred to as NAU QSP Site 875 and GLCA Accession 82, dates to 20,082 ±346 calendar years B.P. (Mead and Agenbroad 1989; Mead and Agenbroad 1992). The dates are based on radiocarbon dates of 16,630 ±280 on associated *Mammuthus* dung. The average age of these dates yield 20,082 calendar years B.P. for my spatiotemporal analysis.

Dung morphology identification of *Bison* sp. (Mead and Agenbroad 1989; Mead and Agenbroad 1992) and I did not view these specimens.

35) Martinez Gravel Pit (N 35.25, W 106.50)

Martinez Gravel Pit also referred to as 6073 in NeotomaDB, dates to 13341 ±30 calendar years B.P. and 110,000 calendar years B.P. (Lucas et al. 1988; Smartt et al. 1991; NeotomaDB). The dates are based on relative dating of the boundaries of the Edith Formation that is approximately 11,500 and 110,000, respectively. The average age of these dates yield 61,655 calendar years B.P. for my spatiotemporal analysis.

Bison latifrons (Lucas et al. 1988; Smartt et al. 1991) had an MNI of 1 listed in NeotomaDB with no osteological context and I did not view this specimen.

36) Marysvale (N 38.37, W 112.12)

Marysvale also referred to as 7682 in NeotomaDB, dates to 603 ±37 calendar years B.P. and 1379 ±12 calendar years B.P. (Gillin and Allen 1941; NeotomaDB). The dates are based on radiocarbon dates of unspecified remains resulting 650 and 1500 years B.P. The average age of these dates yield 978 calendar years B.P. for my spatiotemporal analysis.

Bison bison listed in NeotomaDB with no osteological context and I did not view this specimen.

37) Mastodon Sinkhole (N 39.14, W 111.23)

Mastodon Sinkhole, also referred to as42EM231V and 6315 in NeoMap, dates to the Pleistocene (NeoMap) which places it into Rancholabrean Land Mammal Age (160,000 to 14,000 calendar years B.P.). The date is based on the co-occurrence of *Bison* sp. with *Mammut* *americanum* and *Equus* sp. For my spatiotemporal analysis of this locality, I have created an age point of 14,000 calendar years B.P.

Bison sp. listed in NeoMap database with no osteological context; I did not view this specimen.

38) Mesa Verde site 866 (N 37.12, W 108.50)

Mesa Verde site 866, also referred to 5320 in NeotomaDB and 1286 in NeoMap, dates to 778 ±18 calibrated years B.P. and 856 ±37 calibrated years B.P. (Anderson 1966; NeotomaDB; NeoMap) that places it into Pueblo III of the Pecos Classification that ranges 650 to 850 calendar years ago. The date is based on radiocarbon dates of unspecified remains resulting 880 years B.P. and 950 years B.P., respectively (Anderson 1966; NeotomaDB; NeoMap). The average age of these Pueblo III ranges yield 750 calendar years B.P. for my spatiotemporal analysis.

Bison bison listed in NeotomaDB and NeoMap databases with no osteological context and I did not view these specimens (NISP of 3, MNI of 1).

39) Mesa Verde site 875 (N 37.12, W 108.50)

Mesa Verde site 875, also referred to 5318 in NeotomaDB and 1284 in NeoMap, dates to 856 ±37 calibrated years B.P. and 927 ±3 calibrated years B.P. (Anderson 1966; NeotomaDB; NeoMap) which places it into Pueblo II of the Pecos Classification that ranges from 850 to 1100 calendar years ago. The date is based on radiocarbon dates of unspecified remains resulting 950 years B.P. and 1000 years B.P., respectively (Anderson 1966; NeotomaDB; NeoMap). The average age of these Pueblo II ranges yield 975 calendar years B.P. for my spatiotemporal analysis.

Bison bison listed in NeotomaDB and NeoMap databases with no osteological context and I did not view these specimens (NISP of 1, MNI of 1).

40) NA9074 (N 36.92, W 112.57)

NA9074, also referred to as Kanab Creek, dates to the Pueblo I culture and potentially the Pueblo II culture (GRCA archival database) that ranges from 850 to 1300 calendar years ago (Pecos Classification). The average age of these Pueblo I and Pueblo II ranges yield 1075 calendar years B.P. for my spatiotemporal analysis.

Middle phalanx (from Lot.2) (Figure 18) of *Bison* sp. Tendon imprint in the dorsal surface is deep (character 1) which occurs in *Bison* 11/14 times and in *Bos* 4/14. The most parsimonious taxon as identified here is *Bison*.

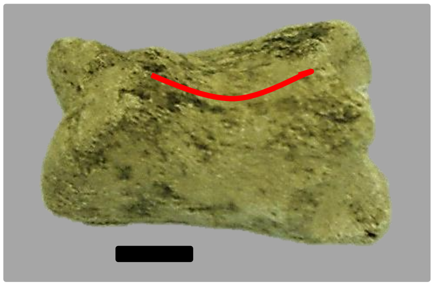


Figure 18. NA9074 *Bison* middle phalanx in dorsal view (anterior left). Red line indicates the deep tendon imprint on the dorsal surface. Scale equals 1 cm.

41) NA9074 S-213 (N 36.86, W 112.79)

NA9074 S-213, also referred to as Mt. Trumbull and MNA AZ.B:1:23, dates to the Pueblo II culture and potentially Virgin Anasazi (GRCA archival database) that ranges from 850 to 1100 calendar years ago (Pecos Classification). The average age of these Pueblo II ranges yield 975 calendar years B.P. for my spatiotemporal analysis.

Middle phalanx was labeled as *'Bos'*, now identified as *Bison* cf. *B. bison*. Tendon imprint in the dorsal surface is deep (character 1) that occurs in *Bison* 11/14 times and in *Bos* 4/14. Sharply angled step in the posterior margin on the proximal surface of the front phalanges (character 3) that occurs in *Bison* 12/14 times and in *Bos* 0/14. The most parsimonious taxon as identified here is *Bison*.

42) Oak Haven (N 37.54, W 111.25)

Oak Haven, also referred to as NAU QSP Site 881 and GLCA Accession 82, dates to 10,377 ±115 calendar years B.P. and 13,530 ±125 calendar years B.P. (Mead and Agenbroad 1989; Mead and Agenbroad 1992). The dates are based on radiocarbon dates of 9180 ±100 and 11,690 ±120, respectively, on associated *Quercus gambelii* wood. The average age of these dates yield 11,958 calendar years B.P. for my spatiotemporal analysis.

Dung morphology identification of *Bison* sp. (Mead and Agenbroad 1989; Mead and Agenbroad 1992) and I did not view these specimens.

43) O'Malley Shelter (N 37.52, W 114.27)

O’Malley Shelter, also referred to as 6162 in NeotomaDB and 2774 in NeoMap, dates to 5403 ±47 calendar years B.P. and 7939 ±183 calendar years B.P. (Fowler et al. 1973; NeotomaDB; NeoMap). The dates are based on radiocarbon dates of 4630 years B.P. and 7100 ±190 years B.P., respectively, on associated charcoal with *Bison bison*. The average age of these dates yield 6739 calendar years B.P. for my spatiotemporal analysis. The age of the site suggests that *Bison bison* may be questionable because it would then be the oldest record of *Bison bison* by at least 400 years (McDonald and Lammers 2002); *Bison antiquus* is more parsimonious.

Bison bison (Fowler et al. 1973) listed in NeotomaDB and NeoMap database with an NISP of 2 and an MNI of 1 with no osteological context; I did not view these specimens.

44) Pharo Village (N 39.00, W 112.00)

Pharo Village, also referred to as 6191 in NeotomaDB and 2848 in NeoMap, dates to 647 ±72 calendar years B.P. and 711 ±76 calendar years B.P. (Marwitt 1968; NeotomaDB; NeoMap). The dates are based on radiocarbon dates of 690 ±90 years B.P. and 760 ±80 years B.P., respectively, on associated wood with *Bison bison*. The average age of these dates yield 681 calendar years B.P. for my spatiotemporal analysis.

Bison bison (Marwitt 1968) listed in NeotomaDB and NeoMap databases with an NISP of 18 with no osteological context and I did not view these specimens.

45) Pine Springs (N 41.02, W 109.37)

Pine Springs, also referred to as 48SW101and 4820 in NeotomaDB, dates to 8560 ±237 calendar years B.P. (Sharrock 1966; Frison 1978; NeotomaDB). The dates are based the co-occurrence of *Bison bison* with *Camelops* sp., additionally, the radiocarbon dates of 7695 ±195 on associated bone collagen with *Bison bison* remains. The average age of these dates yield 8560 calendar years B.P. for my spatiotemporal analysis. The age of the site suggest that *Bison bison* may be questionable because it would then be the oldest record of *Bison bison* by at least 400 years (McDonald and Lammers 2002), *Bison antiquus* is more parsimonious.

Bison bison (Frison 1978) listed in NeotomaDB with no osteological context and I did not view this specimen.

46) Point of Pines (N 33.25, W 109.62)

Point of Pines, also referred to as 5856 in NeotomaDB and 2236 in NeoMap, dates to the Canyon Creek Phase 543 ±28 calendar years B.P. and the Point of Pines Phase 595 ±35 calendar years B.P., both phases belong to the Pueblo IV (Stein 1963; Agenbroad and Haynes 1975; NeotomaDB; NeoMap). The dates are based on radiocarbon dates of 525 ±25 and 587 ±38, respectively, on unspecified remains. The average age of these dates yield 573 calendar years B.P. for my spatiotemporal analysis.

Bison bison (Stein 1963) listed in NeotomaDB and NeoMap databases with no osteological context. An MNI of 1 from the Canyon Creek Phase and an MNI of 1 from the Point of Pines Phase and I did not view these specimens.

47) Porcupine Cave (N 41.00, W 111.00)

Porcupine Cave at the Bridge Junction locality, also referred to as 7680 in NeotomaDB, dates to 542 ±71 calendar years B.P. (Heaton 1988; NeotomaDB). The date is based on radiocarbon dates of 510 ±75 on an associated *Ursus americanus* bone with *Bison bison*. The average age of these dates yield 542 calendar years B.P. for my spatiotemporal analysis.

Bison bison (Heaton 1988) listed in NeotomaDB with no osteological context with an NISP of 1. I did not view this specimen.

48) Red Horse Wash (N 35.79, W 111.92)

Red Horse Wash at the Harbison Cave locality, also referred to as NA9528, dates to the Cohonina culture (MNA archive database) that places it into Pueblo II of the Pecos Classification that ranges from 850 to 1100 calendar years B.P. The age is based on Tusayan Polychrome ceramic style potsherds. The average age of these Pueblo II ranges yield 975 calendar years B.P. for my spatiotemporal analysis.

The naviculocuboid of *Bison bison* (from Lot.4) was listed as ‘bone’ and a calcaneum of *Bison bison* (from Lot.1) that was listed as ‘feces’ in the MNA archival database. The calcaneum has a rounded continuous curve forming the margin of the sustentaculum (character 2) that occurs in *Bison* 24/26 times and in *Bos* 0/15. Naviculocuboid has a continuous surface connecting the distal articular surface for the metatarsal and that of the fused meso-ectocuneiform (character 1) that occurs in *Bison* 19/23 times and in *Bos* 7/12. The articular surface for the metatarsal is rounded in an anteroposterior direction (character 2) that occurred in *Bison* 18/23 times and in *Bos* 0/13. The ventromedial portion of the posterior surface is not scooped out so that the medial edge barely stands out in a poorly defined ridge (character 3) which occurs in *Bison* 14/22 times and in *Bos* 0/13.

49) Ridge Ruin (N 35.28, W 111.99)

Ridge Ruin dates to the Hohokam culture, AD 1087 to AD 1207 (Agenbroad and Haynes 1975; O’Hara 2008) which places it into Pueblo III of the Pecos Classification that ranges from 650 to 850 calendar years B.P. The age of the site is based on the Chacoan style masonry (O’Hara 2008). The average age of these Pueblo III ranges yield 750 calendar years B.P. for my spatiotemporal analysis.

This site is listed to have *Bison bison* (Agenbroad and Haynes 1975) with no osteological context and I did not view these specimens.

50) Sand Dune Cave (N 37.03, W 110.70)

Sand Dune Cave, also referred to as NA7523 as part of the Glen Canyon Project, dates to the Basketmaker culture (MNA archival database) that places it between the Basketmaker III and Basketmaker I of the Pecos Classification that ranges from 1300 to 10,000 calendar years B.P. The average age of these Basketmaker ranges yield 5650 calendar years B.P. for my spatiotemporal analysis.

A “BONE” (from Lot.133) is recorded in the MNA archival database and is now reidentified as a proximal front phalanx of *Bison* sp. The distal two-thirds of the lateral margin is curved (character 1) that occurs in *Bison* 10/24 times and in *Bos* 1/14. Shallow pits on the dorsal face of the proximal end exist (character 3) that occurs in *Bison* 16/24 times and in *Bos* 5/14. The most parsimonious taxon as identified here is *Bison*.

51) Sandblast Cave (N 36.87, W 112.00)

Sandblast Cave, also referred to as 7710 in NeotomaDB and 4875 in NeoMap, dates to 10,905 ±220 calendar years B.P. and 15,710 ±1014 calendar years B.P. (Emslie 1987; Emslie 1988; Mead and Agenbroad 1989; Mead and Agenbroad 1992; NeotomaDB; NeoMap). The dates are based on radiocarbon dates of 9582 ±160 and 16,110 ±680 on associated *Oreamnos* dung. The average age of these dates yield 13,704 calendar years B.P. for my spatiotemporal analysis.

Bison sp. (Emslie 1987; Emslie 1988) upper premolar. Based on the age of the site (9580 – 33,100 years B.P.), the species identification cannot be *Bison bison* nor *Bos taurus*, however *Bison antiquus* or *Bison latifrons* is more parsimonious. Additionally, dung morphology identified as *Bison* sp. (Mead and Agenbroad 1989; Mead and Agenbroad 1992) is reported; I did not view these specimens.

52) Shrub Ox Alcove (N 37.30, W 110.94)

Shrub Ox Alcove, also referred to as NAU QSP Site 882 and GLCA Accession 82, dates to 15,003 ±358 calendar years B.P. (Mead and Agenbroad 1989; Mead and Agenbroad 1992; Withers and Mead 1993). The dates are based on radiocarbon dates of 12,690 ±180 years B.P. on an oak twig associated with *Bison* sp. dung. The average age of these dates yield 15,003 calendar years B.P. for my spatiotemporal analysis.

Dung morphology identification of *Bison* sp. (Mead and Agenbroad 1989; Mead and Agenbroad 1992); I did not view these specimens.

53) Smoking Pipe (N 40.12, W 11.62)

Smoking Pipe, also referred to as 42UT150 and 6363 in NeotomaDB, dates to the 621 ±80 calendar years B.P. (NeotomaDB). The date is based on a radiocarbon date on a *Bison bison* bone from 640 ±110 years B.P. (Billat 1985; NeoMap). The average age of this date yields 621 calendar years B.P. for my spatiotemporal analysis.

Bison bison (Billat 1985) listed in NeotomaDB with no osteological context of an MNI of 8 and an NISP of 1831with evidence of human butchering. I did not view these specimens.

54) Snake Rock Village (N 38.75, W 111.25)

Snake Rock Village, also referred to as 6194 in NeotomaDB and 2851 in NeoMap, dates to 611 ±37 calendar years B.P. and 858 ±40 calendar years B.P. (Aikens 1967; NeotomaDB; NeoMap). The dates are based on radiocarbon dates of 650 ±30 and 950 ±30 on associated wood. The average age of these dates yield 736 calendar years B.P. for my spatiotemporal analysis.

Bison bison listed in NeotomaDB and NeoMap databases with no osteological context and an NISP of 1and an MNI of 1. I did not view this specimen.

55) Snaketown (N 33.19, W 111.91)

Snaketown, also referred to as U:13:1 and 5674 in NeotomaDB; dates to 835 ±109 calendar years B.P. and 1799 ±342 calendar years B.P. (Haury 1965; Agenbroad and Haynes 1975; NeotomaDB). The dates are based on radiocarbon dates of 900 ±120 and 1810 ±300 on charcoal and plant matter associated with *Bos taurus* remains. The average age of these dates yield 1433 calendar years B.P. for my spatiotemporal analysis.

Reported as *Bos taurus* but my assessment states that they are most likely *Bison*. *Bison* sp. listed as '*Bos taurus*' in database with no osteological context of an NISP of 2 and an MNI of 1; however, the site is too old for *Bos taurus* to exist here. A few explanations may result: 1) these specimens are *Bison bison*, 2) the dates could be erroneous, or 3) the initial identification of *Bos* may have also been misleading and may in actuality be an elk or similar artiodactyl. At this time it would seem most parsimonious that the specimen is *Bison bison*.

56) Spotten Cave (N 40.00, W 111.75)

Spotten Cave, also referred to as 42UT104 and 6358 in NeotomaDB, dates to 684 ±82 calendar years B.P. (Cook 1980; NeotomaDB). The dates are based on radiocarbon dates of 730 ±90 on unspecified remains. The average age of these dates yield 684 calendar years B.P. for my spatiotemporal analysis.

Bison sp. listed in NeotomaDB with no osteological context of an MNI of 1. I did not view this specimen.

57) Stanton's Cave (N 36.50, W 111.83)

Stanton's Cave, also referred to as NAU QSP Site 9121, GRCA Accession 4597, Ariz. C:5:3, 5747 in NeotomaDB, and 2008 in NeoMap. Stanton's Cave dates to 6599 ±230 calendar years B.P. and 16,677 ±694 calendar years B.P. for Level 3, and 21,035 ±978 calendar years B.P. to today for the Surface Level (Harington and Euler 1984; Mead and Agenbroad 1989; Mead and Agenbroad 1992). The dates are based on radiocarbon dates of 5760 ±200, 13,770 ±500, and 17,300 ±800, respectively, on dung, dung, and *Oreamnos harringtoni* dung, respectively. The average age of these dates yield 14,191 calendar years B.P. for my spatiotemporal analysis.

Bison sp. listed in the GRCA archival database with no osteological context from the Surface Level and Level 3. Additionally, I re-evaluated specimen number GRCA 55497, from the surface level, identified as a *Equus* femoral head (Harington and Euler 1984) is now identified as a *Bison* sp. proximal femoral head with a recessed hemisphere fovea as in *Bison*, whereas *Equus* have a triangular notch for their fovea, which if the attachment for the *ligamentum teres formis*.

58) Sudden Shelter (N 38.76, W 111.45)

Sudden Shelter, also referred to as 45SV6, 5856 in NeotomaDB, and 2225 in NeoMap, dates to 7174 ±252 calendar years B.P. and 7090 ±87 calendar years B.P. (Lucias and Colville 1980; NeotomaDB). The dates are based on radiocarbon dates of 6310 ±240 and 7090 ±85, respectively, on charcoal associated with *Bison bison*. The average age of these dates yield 7458 calendar years B.P. for my spatiotemporal analysis.

Bison bison is listed in NeotomaDB and NeoMap databases with no osteological context but with evidence of human butchering. The age of the site would suggest that *Bison bison* is erroneous as the site is too old for bison and would be the earliest occurrence of *Bison bison* (McDonald and Lammers 2002). A few explanations may result: 1) these specimens are *Bison antiquus*, 2) the dates could be erroneous, or 3) the initial identification of *Bison bison* may have also been misleading and may in actuality be an elk or similar artiodactyl. At this time it would seem most parsimonious that the specimen is *Bison* sp.

59) Texas Creek Overlook (N 39.62, W 107.87)

Texas Creek Overlook, also referred to as Bison Hump Shelter, 5RB2435, 5197 in NeotomaDB, and 1148 in NeoMap. Texas Creek Overlook dates to 458 ±63 calendar years B.P. (Creasman and Scott 1987; NeotomaDB, NeoMap). The dates is based on a radiocarbon date of 430 ±50 on charcoal associated with *Bison bison*. The average age of these dates yield 458 calendar years B.P. for my spatiotemporal analysis.

Bison bison listed in NeotomaDB and NeoMap databases with no osteological context of an NISP of 1and an MNI of 1. I did not view this specimen.

60) Upper Sand Island Site (N 37.17, W 109.85)

Upper Sand Island Site dates to 11,000 to 13,000 calendar years B.P. (Mead 2002; Malotki and Wallace 2011) which places it into Clovis Phase of the Pecos Classification that ranges from 11,000 to 13,500 calendar years ago. The average age of the provided age range yields 12,000 calendar years B.P. for my spatiotemporal analysis.

Bison sp. pictograph based on cloven hooves, a pronounced dorsal hump, and recurved horns (Malotki and Wallace 2011). I did not view this specimen.

61) Walnut Canyon National Monument (N 35.17, W 111.51)

Walnut Canyon National Monument dates to AD 1150 to AD 1220 (Starkovich 2011) that places it into Pueblo III of the Pecos Classification, which ranges 650 to 850 calendar years ago. The date is based on ceramic styles (Starkovich 2011). The average age of these Pueblo III ranges yield 750 calendar years B.P. for my spatiotemporal analysis.

Reported as *Bos* in database but my assessment indicates *Bison*. (Cat# 1746) listed as *Bison*/*Bos*. Improbable to be *Bos taurus* because *Bos* do not enter North American until after AD 1565. A few explanations may result: 1) these specimens are *Bison* sp., 2) the dates could be erroneous, or 3) the initial identification of *Bos* may have also been misleading and may in actuality be an elk or similar artiodactyl. At this time, it would seem most parsimonious that the specimen is *Bison* sp. I did not view this specimen.

62) Wetherill Mesa (N 37.12, W 108.50)

Wetherill Mesa site 1644 is also referred to as 5316 in NeotomaDB and 1282 in NeoMap. Wetherill Mesa dates to 1237 ±34 calendar years B.P. (Hayes and Lancaster 1975; NeotomaDB; NeoMap). The dates are based on the Pithouse A's foundation style dating to 1300 years B.P. The average age of these dates yield 1237 calendar years B.P. for my spatiotemporal analysis.

Bison bison bone sculpted as a tool listed in database with no osteological context. I did not view this specimen.

63) Whiskey Creek (N 33.87, W 108.62)

Whiskey Creek, also referred to as LA 4986, 5971 in NeotomaDB, and 2438 in NeoMap, dates to 600 ±32 calendar years B.P. and 2310 ±50 calendar years B.P. (Heller 1976; NeotomaDB; NeoMap) that places it between Pueblo III and Early Basketmaker II of the Pecos Classification which ranges 650 to 3200 calendar years ago. The date is based on ceramic styles (Heller 1976; NeotomaDB; NeoMap). The average age of these Pueblo III and Basketmaker ranges yield 1540 calendar years B.P. for my spatiotemporal analysis.

Bison bison listed in the database with no osteological context. I did not view this specimen.

64) Wither's Wallow (N 37.54, W 111.25)

Wither's Wallow, also referred to as NAU QSP Site 883 and GLCA Accession 82, dates to 13,900 ±226 calendar years B.P. (Mead and Agenbroad 1989; Mead and Agenbroad 1992). The dates are based on radiocarbon dates of 12,010 ±60 on *Mammuthus* dung associated with *Bison* sp. dung. The average age of these dates yield 13,900 calendar years B.P. for my spatiotemporal analysis.

Dung morphology identified as *Bison* sp. (Mead and Agenbroad 1989; Mead and Agenbroad 1992) and I did not view these specimens.

65) Zion National Park (N 37.28, W 113.08)

Zion National Park dates to the Pleistocene (Smith and Santucci 2001; Justin Hall, Zion NPS personnel, pers. comm. 2013) that places it into Rancholabrean Land Mammal Age (160,000 to 14,000 calendar years B.P.) based on the presence of *Bison* (Bell et al. 2004). The date is based on the geology of the Pleistocene gravels of the locality. For my spatiotemporal analysis of this locality, I have created an age point of 14,000 calendar years B.P.

Bison antiquus thoracic vertebral centrum (ZION 12396) identified by James E. Martin in 1994 (J. Hall pers. comm. 2013). Surface collection from right fork of North Creek in Zion National Park in Washington County, Utah. I viewed this specimen digitally and I agree, at minimum, that the specimen is *Bison* sp.

Spatiotemporal Analysis

ArcGIS was used to spatially display and analyze the data. ArcGIS is a proprietary geographic information system that stores, analyzes, and displays geospatially-constrained data. When pairing spatial with temporal attributes, the combination is a spatiotemporal experiment. First, all the data for *Bison* are added into data managing software. This data includes latitude and longitude coordinates for a site, site name, relative or absolute age, publication source, notes, etc. Then, a data conversion process is implemented within ArcGIS whereby the database is imported in its entirety and mapped based on the stored latitude and longitude coordinates. For this reason a projected coordinate system specific to the longitudinal location of the CP was selected (the North American Datum 1983 Universal Transverse Mercator Zone 12 North (NAD83 UTM Zone 12N)). This projection preserves area, distance, shape, and direction over larger, regional areas (Price 2012) and is preferred by the NPS. Additionally, state boundaries were mapped for geographical reference along with and an outline of the CP.

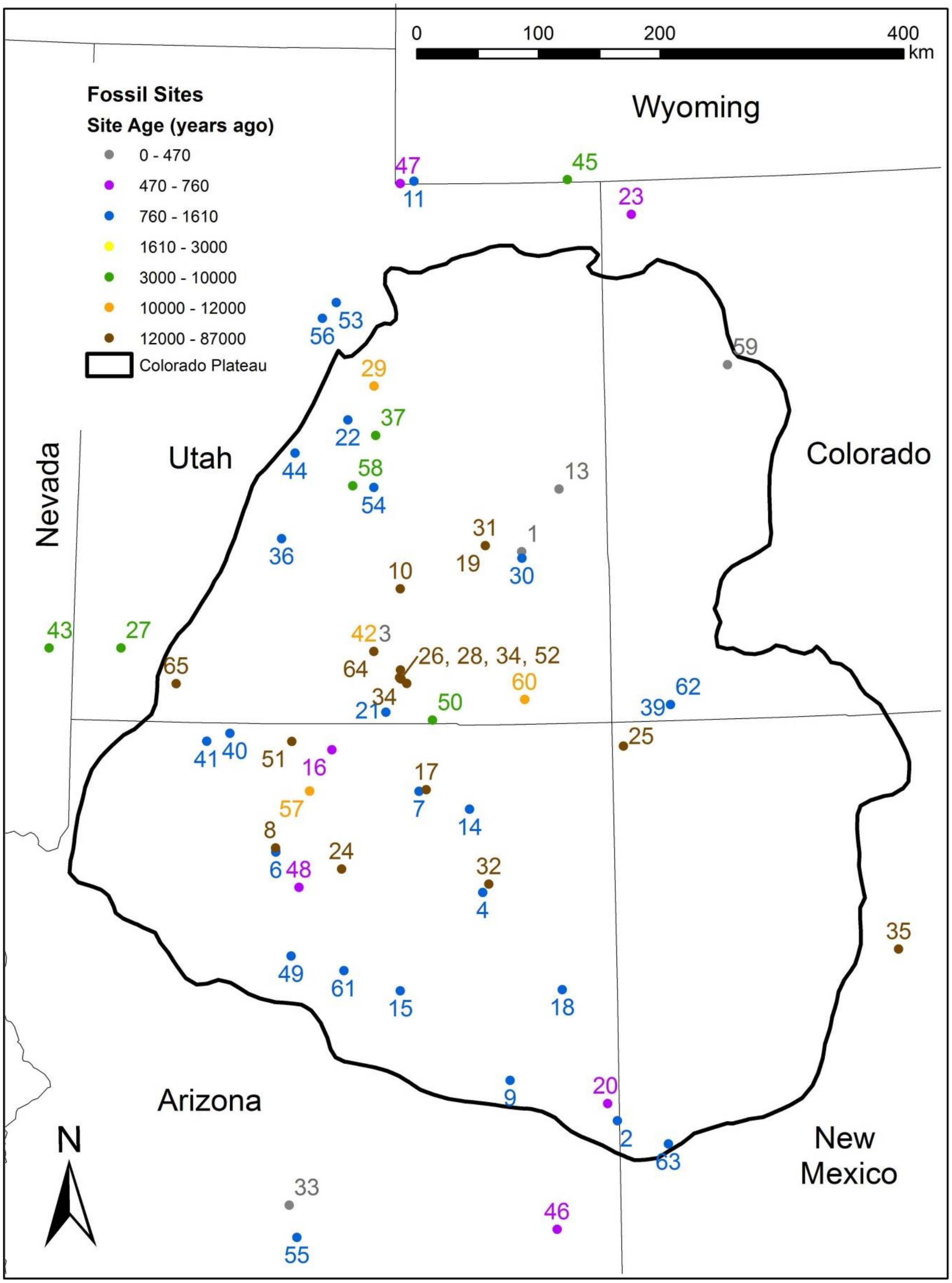


Figure 19. Fossil bison sites on the Colorado Plateau. Color of dots and numbers refer to site age (see legend). Numbers refer to site Key ID numbers. Years ago refers to calendar years B.P.

Seasonal Range Analysis

Actual seasonal range migration was digitized from Larson et al. (2009: 3), which was first collected from AZGFD. Larson et al. (2009) reported that "all individuals [bison] traveled between 36-44 km south and southwest from the House Rock Valley Wildlife Area to Flint Creek, Crystal Creek, and White Creek." However, that is a linear Euclidean distance that occurred only between the 5 months of March to August in 2005. Four bison were tracked, and mapped; although Larson's bison number 1 is difficult to duplicate and I did not include this bison in the cost distance analysis because the path is uncertain and incomplete due to obstruction by the other 3 superimposed bison paths.

Larson et al. (2009) reported that GRCA biologists claimed that "during the warm months of the year," the herd migrates to HRVWA to give birth as "a throwback to the time when animals were confined there." Presumably, the GRCA biologists referred to spring (April) and early summer (May) (Meagher 1973). Alternatively, the bison are responding to an innate natural seasonal range migration from the snow-covered high elevations to the desirable birthing grounds of the lower elevations, and, in doing so, are returning to their own birthplace to give birth, which is a well-accepted theory (Meagher 1973; Cannon 2001).

After birthing in the HRVWA, "most of the individuals migrate back to [GRCA] in the late summer and fall, where they can escape hunting pressure," as cited in personal communication from RV Ward in 2008 (Larson et al. 2009). However, alternatively, the bison are migrating to more easily accessible resources, such as water and forage, that are not seasonally accessible or plentiful in the HRVWA.

The cost distance of one-way migration ranges from 103 to 179 kilometers as opposed to the cited linear distance of 36-44 kilometers (Larson et al. 2009). Additionally, Holton (pers.

comm. 2013) reported that the House Rock bison were easily making their way onto the Powell Plateau as of summer 2013. These evidences support the conservative 56-kilometer buffer used in my analyses shown in Figure. Moreover, to have an extrapolated total yearly seasonal range, it is conceivable that the actual travel distance is at least the quotient of dividing the 5-month totals of 103 and 179 kilometers by 5, and multiply by 12 for the product of 247 and 429 kilometers, respectively. The percent error and percent difference for each respective bison path are shown in Table 1.

Table 1. Comparison of Larson et al. (2009) Euclidean distances and actual migration distances over 5 months with percent differences and errors reported.

Bison #	Euclidean Distance (km)	Cost Path Distance (km)	Difference in Error (km)	Extrapolated Yearly Sum of Cost Path (km)	Percent Difference (%)	Percent Error (%)
*1	9.11	36.4	27.29	87.4	119.9	74.97
2	43.61	103.0	59.39	247.2	81.0	57.66
3	35.06	179.0	143.94	429.6	134.5	80.41
4	41.29	116.0	74.71	278.4	95.0	64.41

*Erroneous data is due to insufficient data because of superimposed paths of the last three tracks

Spatiotemporal Analysis of Fossil *Bison* Seasonal Ranges

The following groupings are used in Figure 20 and are loosely based on Ahlstrom et al. (1993) and Huffer (2013) temporal scale of cultural remains, and are related to the Pecos Classification. In this study, the dates of each Period were converted to calendar years B.P., meaning that the date of 1776 AD was subtracted from 1950 AD to equate 174 calendar years B.P. (herein after years B.P.). I use 1950 AD because of convention and typically used as the baseline for calibrating radiocarbon (C^{14}) dates, too. The subsequent 5 groupings are chosen to reflect the cultural similarities interculturally and differences intraculturally.

1. The first grouping in Figure 20A *Bison* localities includes the Rancholabrean LMA (160,000 to 14,300 years B.P), the Pre-Clovis Period (14,300 to 13,500 years B.P.), the Clovis Period (13,500 to 11,000 years B.P.), and the Folsom Period (11,000 to 10,000 years B.P.). In part, this is also referred to as the Paleoindian Period (Huffer 2013), where people have little to no interactions with *Bison*, at least worth of impact on community structures of *Bison*.
2. The second grouping in Figure 20B dates to the time of Basketmaker I cultural remains ranging from 10,000 to 3,200 years B.P. This, in part, is also referred to as the Archaic Period where *Homo sapiens* have primarily a nomadic lifestyle where *Bison-Homo* interactions are apparent through hunter-gatherer feeding strategies (Huffer 2013).
3. The third grouping in Figure 20C include Early Basketmaker II (3,200 to 1,950 years B.P.), Late Basketmaker II (1,950 to 1,700 years B.P.), and Basketmaker III (1,700 to 1,300 years B.P.). This, in part, is also referred to as the Preformative Period where people cultures were adopting a semi sedentary lifestyle, beginning horticultural feeding strategies to supplement hunting game that suggests continued human interactions with *Bison*. It should be noted that this is one of the least understood periods (Huffer 2013).
4. The fourth grouping in Figure 20D includes the ceramic phases of Pueblo I (1,300 to 1,100 years B.P.) and Pueblo II (1,100 to 850 years B.P.). This, in part, is also referred to as the Formative Period where agriculture is intensified and ceramic styles are apparent, though, hunting of large and small game is still prominent (Huffer 2013) that suggests continued human interactions with *Bison*.

5. The final grouping in Figure 20E includes Pueblo III (850 to 650 years B.P.), Pueblo IV (650 to 400 years B.P.), and Pueblo V (400 years B.P. to present) cultural associations with *Bison*. This, in part, is also referred to as the Late Prehistoric, Protohistoric, and Historic Periods (Huffer 2013). These are all combined to create one period, here referred to as the 'Contemporary Period' that is comparable to the time of the previous four large periods.

Each of the 64 sites with *Bison* in Figure 19 then had the buffer of 56 kilometers applied to create the potential seasonal range area on the CP. Subsequently, the sites were then separated into their respective periods as described above resulting in Figure 20.

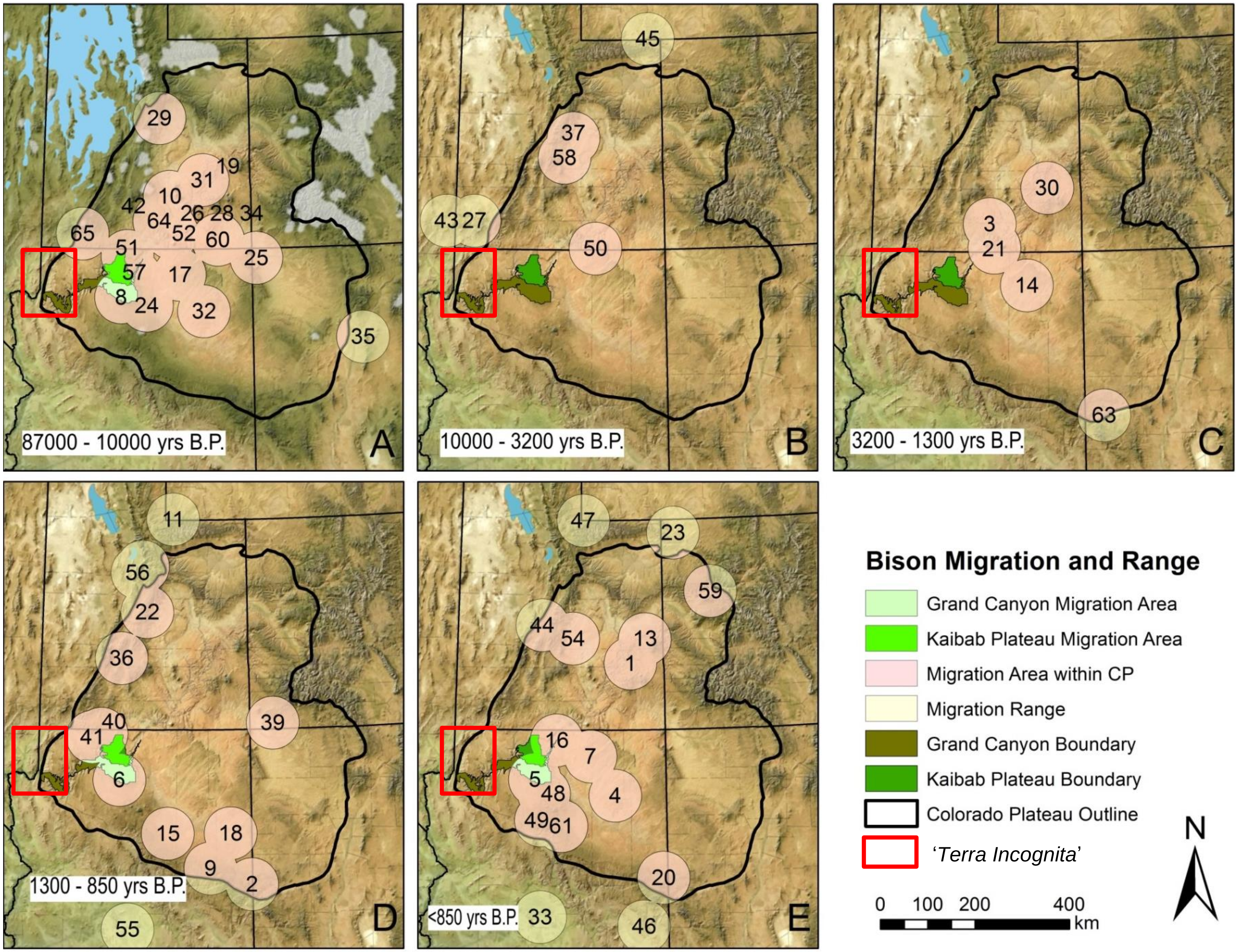


Figure 20. Colorado Plateau *Bison* site localities, divided by Pecos Classifications and the Rancholabrean Land Mammal Age.

Figure 20. (continued) Approximate percent land cover by section is given in Table 2. A) Map background is a reconstruction of the area during the Ice Ages as in Figure 2, 25,000 years ago, the white coloring on the mountains represent permanent Alpine glaciers, and Lake Bonneville (Blakey and Ranney 2008). B), C), D), and E) maps of geomorphology circa the 1930s before the damming of the Colorado River as in Figure 3 (Blakey and Ranney 2008) (yrs B.P. = years Before Present). '*Terra Incognita*' (Mead 2002; Mead 2004).

For each period represented in Figure 20, additional analyses are performed. First, each locality within each time frame is given a buffer radius of 56 kilometers (35 miles). This buffer is conservative because it is calculated based on a seasonal range migration of the House Rock Valley bison herd from the HRVWA locality to the Powell Plateau as a Euclidian distance (linear, from point A to point B), not as a cost distance (actual path, seldom linear). Euclidian distance, instead of cost distance, was chosen for a conservative estimate of minimum seasonal range migration patterns because *Bison* of the past most likely had seasonal ranges larger than the managed House Rock Valley bison herd. However, the seasonal range of the House Rock Valley bison is very short-ranged and is limited by few fences (Minard 2010) to the North and the steep Grand Canyon incision to the South, East, and West.

Recently, in the western portion of GRCA, the javelina (*Pecari tajacu*) were observed moving into the Grand Canyon Inner Gorge from the South, crossing the Colorado River, and dispersing onto the North Rim side of the canyon and river (Mead 2004; Holton pers. comm. 2013). It is not out of reason to predict that *Bison*, now and thus in the past, had similar climbing and navigating abilities through the canyons of the Grand Canyon as the javelina, another Artiodactyl. *Bison* are excellent swimmers (Fuller 1960; Larter et al. 2003) and would not be deterred by the Colorado River.

In the sense of geospatial analysis, digitally clipping the seasonal range buffer to the CP outline excludes the area outside of the CP and then the areal extent of the clipped seasonal range area is calculated. Percent of total seasonal range buffer zones within the CP were calculated using Equation 1.

Equation 1. $\frac{\text{Clipped Buffer Area to CP}}{\text{Area of whole CP}} \times 100 = \%\ \text{Minimum Seasonal Range Area Cover of CP}$

The result is 56.7% (Equation 1); however, this result describes all of the sites over the past 160,000 years combined and is not representative of the bison nativity in each, and thus Equation 1 is applied to each period in Figure. GRCA boundaries were digitized, as well as the KNF boundaries for performing percent area cover analysis. Equation 2 and Equation 3 were used both to complement Equation 1 in producing the results from the separated periods in Table 2.

Equation 2. $\frac{\text{Clipped Buffer Area to GRCA}}{\text{Area of whole GRCA}} \times\ 100 = \%\ \text{Minimum Seasonal Range Area Cover of GRCA}$

Equation 3. $\frac{\text{Clipped Buffer Area to KNF}}{\text{Area of whole KNF}} \times\ 100 = \%\ \text{Minimum Seasonal Range Area Cover of KNF}$

However, in FigureB, GRCA and KNF, and in FigureC, GRCA and KNF, the 0% results indicate that more data need to be collected from the area known as ‘*Terra Incognita*,’ which is an area poorly studied (red box in Figure) (Mead 2002; Mead 2004), to complete the western portion of the GRCA, the KNF, and the GGC. Yet, the lack of bison may well be an indicator of an ever-continuing process of expansion and retraction of the bison’s range in response to climatic change; perhaps, not many remains of anything were preserved due to inadequate climatic conditions for preservation.

Table 2. Percent of minimum seasonal range covering defined areas during separate periods from Figure 20.

Figure and Period (B.P. = calendar years B.P.)	CP (%)	GRCA (%)	KNF (%)	GGC (%)
Figure 20A Rancholabrean (160,000 – 10,000 B.P.)	31.0	55.1	98.2	51.0
Figure 20B Archaic (10,000 – 3,200 B.P.)	7.6	0.0	0.0	0.0
Figure 20C Preformative (3,200 – 1,300 B.P.)	11.9	0.03	0.0	2.9
Figure 20D Formative (1,300 – 850 B.P.)	24.5	58.9	95.6	46.6
Figure 20E Contemporary (Less than 850 B.P.)	28.6	54.3	72.5	49.6

According to GRCA officials, during the Rancholabrean of the Late Pleistocene, it is accepted that *Bison* were native at that time to the CP and to GRCA (Mead 2002). Using the results in Table 2:Figure 20A, we now have a baseline at which to compare subsequent periods to, to distinguish *Bison* as native or not native. For GRCA, 55.1% of the area was covered by potential *Bison* seasonal ranges during the Rancholabrean. Similarly, during the Formative and Contemporary Periods, 58.9% and 54.3%, respectively, of the seasonal ranges covering GRCA. Similar patterns exists for the KNF, the GGC, and the CP.

These analyses show that: 1) overall, bison did occupy a majority of the CP throughout the cumulative last 160,000 years; however, when each period is separated the CP was less covered and 2) during recent human occupancy, bison did inhabit the GRCA, GGC, and KNF regions.

CHAPTER 4

DISCUSSION

"I want to ask you to do one thing in your own interest, and in the interest of the country, leave it as it is. You cannot improve on it – not a bit. The ages have been at work on it, and man can only mar it."

—Theodore Roosevelt, excerpt of a speech on May 6, 1903, at the Grand Canyon

Paleozoological Discussion

Sixty-five sites were located on and near the CP and contained *Bison* as compared to previous studies locating 48 total sites, 16 during the Holocene, and only 10 of the Holocene sites are located on the CP (Huffer 2013).

Discussion of *Bison* on the Colorado Plateau

Bison are known not to be frequent cave dwellers (Jass and George 2010: 109), thus finding *Bison* in caves may be significant. The few remains of individuals in caves may reflect a larger, sustainable population adjacent to the fossil site. *Bison* are categorized as low frequenters of the caves, no more than 16.9% of all *Bison* remains are in caves across the contiguous United States (Jass and George 2010). For comparison, approximately 85.7% of bighorn sheep (*Ovis canadensis*) remains are found in caves (Jass and George 2010).

Previous studies rarely identified *Bison* remains because it was traditionally thought that *Bison* did not inhibit the CP, thus creating an unsubstantiated circular argument of, 'if there are thought to be no *Bison* on the CP, *Bison* will not be identified.' However, it would seem that the pre-Colombian cultural trading of *Bison* might not have been traded over long distances but more locally. In addition, through time, the importance of local trading on CP is most certainly variable (Cannon 2001).

Some hypothesize that the bison found in the GGC are carrion from scavengers, bloat-and-float from upstream Colorado River, or goods traded by peoples (as discussed in Mead 2002). To test this, in all cases, evidence for each taphonomic process was considered in the study. To date, of the specimens observed, little taphonomic deterioration and only a few specimens exhibit utilization marks or fluvial alterations thus concluding that the *Bison* were not transferred over large distances; instead, suggest they may have had a local origin.

Future Work

I would add 6 sites for bison potential area coverage. Smith Creek Cave (26WP46) in Nevada because *Bison* sp. are listed to be present at this site and is in proximity to the CP; however, it dates to the Pleistocene (12,600 – 35,000 years B.P.) based on radiocarbon dates on plant matter and bone, respectively. I would add Walton Creek site (5RT11) in Colorado because it lists having *Bos taurus* but dates to 1730 ±225 years B.P. based on associated charcoal. The association of *Bos taurus* in this strata seems improbable as *Bos taurus* was not introduced to North America, alternatively, *Bison bison* would be expected. I would add Beamer's Cabin (AZ C:13:0004 GC) and Furnace Flats (AZ C:13:0010 GC) and both fall between 640 – 1400 AD (1310 – 550 years B.P.), well before *Bos taurus* was introduced to North America. I would also Badger House that is located southeast of GRCA.

Perhaps more importantly, I would like to include the other national parks and monuments, national forests, and Bureau of Land Management lands in the spatiotemporal analysis for more informative results for the rest of the public lands.

Spatiotemporal Discussion

Fifty-one of 65 sites were located directly on the CP and 14 immediately adjacent to the CP. One of the 65, BF Alcove, was cited (Santucci et al. 2001) to have *Bison* remains but resulted in not containing *Bison* remains (Mead and Agenbroad 1989; Mead and Agenbroad 1992; Mead pers. comm. 2014). Usage of ArcGIS clearly illustrates both the geographic extent of *Bison* remains at different sites and how their seasonal ranges have fluctuated through time. The traditional maps of *Bison* range extents (Hornaday 1889; McDonald 1981) need now to include the CP as part of the secondary range earlier than 1300 years B.P., and part of the primary range later than 1300 years B.P.

Ecological Implications

Finding that *Bison* are native to CP, GGC, KNF, and GRCA creates new issues for land managers to contemplate, i.e. - how bison interact with their surrounding environments. Below, I provide some of the morphological, ecological, and physiological differences between bison and cattle, and I discuss the similarities of the House Rock Valley bison (cattalo) and pure bison. I also provide a case study of *Bison* reintroduced to a previously known portion of the prehistoric *Bison* range in Alberta, Canada.

Skeletal Morphology

Bison and *Bos* crania are morphologically distinct with the exception of their teeth (Skinner and Kaisen 1947; Kurtén and Anderson 1980; McDonald 1981). However, within *Bison* alone, the species, modern and fossil alike, are conventionally specifically identified based solely on skulls, and almost exclusively on the horns (Skinner and Kaisen 1947; McDonald 1981). This is an issue for fossil sites where the population overlaps the metrics of 2, sometimes 3, species of

Bison; especially when the sex is unknown, e.g. - large, typically mature, females morphometrically overlap with small, typically young, males (as discussed in Wilson 1978). Some of the fossil species of *Bison* may be representatives of a chronospecies, where there is no distinct change from one species to the next and have many transitional intermediates.

Regardless, almost all *Bison* postcranial bones are diagnostic and morphologically distinct from *Bos* (Lawrence 1951; Olsen 1960; Balkwill and Cumbaa 1992; Lewis et al. 2005). Balkwill and Cumbaa (1992) provide more clarity for each bone and provide statistical probability on the reliability of each character on each bone.

What is a Species?

The definition of species can be a difficult concept to understand, especially considering biological, ecological, evolutionary (usually supported by skeletal morphology), cohesion, phylogenetic, phenetic (phenotypic), and genotypic clustering (De Queiroz 2007: 880). A species may exist under the premise of one or more of these definitions but not in others (Table 3). Cantino and de Queiroz (2010) and De Queiroz (2007) continue to discuss that the definition of a unified conceptualized species only has to “be evolving separately from other lineages.” Under this premise, the House Rock Valley bison have been evolving and thriving, separately from other lineages, in concert with the climate and environment of the Kaibab Plateau area for the last almost 110 years. This herd is also united in their origins to Charles Goodnight’s “cattelo” herds from 1873 in Texas, which were bought by Charles Jesse “Buffalo” Jones (Halbert 2003).

Table 3. Alternative contemporary species concepts and if each defines cattalo a separate species (Adapted from De Queiroz 2007).

Species Concept	Is cattalo a distinct species from *Bison* and *Bos*?	References
Biological	NO, for the first two generations YES, after the third generation	ABA 2014
Isolation	YES	Meagher 1986; ABA 2014
Recognition	YES	ABA 2014
Ecological	YES	Meagher 1986; Mooring and Samuel 1998
Evolutionary	NO	Skinner and Kaisen 1947; Douglas et al. 2011
Cohesion	YES	Meagher 1986; ABA 2014
Hennigian	NO	Mooring and Samuel 1998; Douglas et al. 2011
Monophyletic	YES	Douglas et al. 2011
Genealogical	NO	Douglas et al. 2011; ABA 2014
Diagnosable	YES	ABA 2014
Phenetic	YES	Derr et al. 2012; ABA 2014
Genotypic cluster (definition)	YES	Douglas et al. 2011; ABA 2014

Genetics, Phenotypes, and Adaptability. Widespread across North America, the purity of *Bison* has been under scrutiny and the implications have been under debate. Genetic analyses of *Bison* have been studied intensely by James Derr and his lab members (Derr Lab) in the Department of Veterinary Pathobiology at Texas A&M University (Halbert 2003; Halbert and Derr 2008; Douglas et al. 2011; Derr et al. 2012; Cronin et al. 2013). However, other studies have also exposed light on the purity and relatedness debate of *Bison* and *Bos* (Polziehn et al. 1995; Polziehn et al. 1996; Wilson and Strobeck 1999; Wakeling 2006; Hendrick 2009; Figueroa et al. 2010).

The Derr Lab primarily has studied the public herds of the United States and analyzed which herds are genetically pure for conservation efforts of the species (Dratch and Gogan 2010). *Bos* gene introgressions into *Bison*, Derr et al. (2012) claims, hinder adaptive qualities and result in extinction. However, the study compares the weight gains of hybrid bison on the Santa

Catalina Islands of California to pure bison in a feedlot (Derr et al. 2012). This comparison is unsound on at least 3 fronts: 1) The bison hybrids on the Santa Catalina Islands are in fact, living on an island. Resources are not plentiful but, in the past, mammoths have lived on the Channel Islands and, over time, adapted to the island setting by dwarfing (Agenbroad 2009). If anything, the report by Derr et al. (2012) is documenting the dwarfing effects for the bison population on the islands. 2) The weight gains of feedlot bison are the extreme case of weight gain for bison. Bison in feedlots put on weight between 1.25 to 1.5 times faster than that of grass-fed range bison (SMA 2012). 3) Using weight gain as a metric of adaptability overlooks that it is an environmentally dependent character and not an evolutionary response. Additionally, the American Beefalo Association (2014) show that hybrids, with as little as 3/8 bison genes, are adaptable to varying climates because bison have sweat glands and cattle do not. Furthermore, hybrids exhibit hardiness, longevity, and disease resistance; which are all acceptable evolutionary adaptability characters (Rivals et al. 2007).

Bison and *Bos* are biologically similar but exhibit different phenotypes, nongrazing behaviors, grazing behaviors, and skeletal morphology. Together, these similarities and differences help distinguish the genus and species level designations of *Bison bison* and *Bos taurus* using Linnaean taxonomy. However, the Phylocode (De Queiroz 2007; Cantino and De Queiroz 2010), a taxonomical classification based on phylogeny and evolutionary history, may provide clarity on the hybridization issue of cattalo (Figure 21). Figure 21 shows an example of a hypothesized hybridization clade of *Bison*, *Bos,* and cattalo.

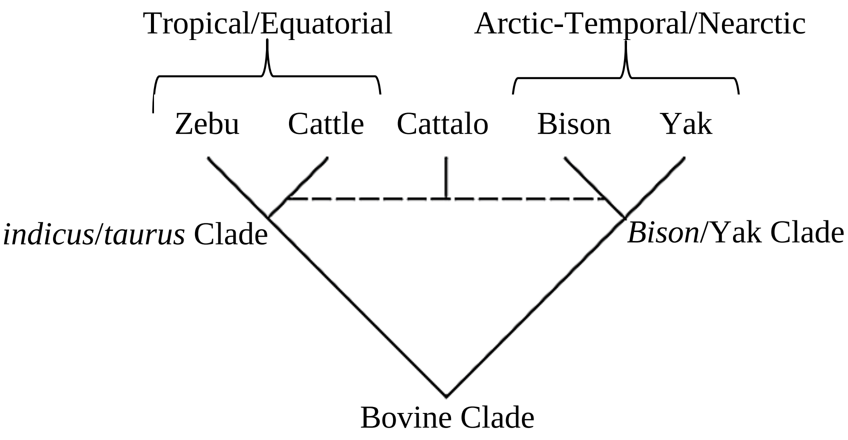


Figure 21. Hypothetical hybridization clade of cattalo with cattle (*Bos taurus*) and bison (*Bison bison*), with Yak (*Bos grunniens*) and Zebu (*Bos indicus*) included to illustrate closest relative relationship and ancestral provenance (clade structure adapted from (Cantino and De Queiroz 2010); provenance data from (Peters and Slen 1964); phylogenetic relationships from (Douglas et al. 2011).

Phenotype. Phenotype refers to the physical appearance of an animal and some physical appearances can also affect the physiological features of that animal, such as hair. Yak and bison have subcutaneous fat and sebaceous glands (sweat glands) surrounding each hair follicle (Peters and Slen 1964; ABA 2014), whereas zebu and cattle do not. The presence of these sebaceous glands and subcutaneous fat are attributed to the yak and bison adapting to the temperature extremes and variations with the arctic and temperate biomes of the Nearctic region (Peters and Slen 1964).

Additionally, the hair coat structure of *Bison* is present in three layers; cattle do not have this multi-level coat structure (Mooring and Samuel 1998). The primary guard hairs of bison are a tightly compact mat at the skin surface, which works similar to down feathers in waterfowl; these are water and wind proof. The dense mat of hair on *Bison* also serves as a seed disperser as the animals migrate, with *Bison* sex and age being specific to certain plant species (Rosas et al. 2008). The secondary hairs are longer and coarser than the primary guard hairs and they repel water from the body. The tertiary hairs, mostly found on the anterior portions of the animal (cape of shoulders and chaps of the front limbs), are the longest and coarsest to wick away water from the body (Peters and Slen 1964). Because of these layers, the hair density of *Bison* is 3 times that of a Hereford in fibers per unit area. As a result, 6-month-old bison calves are as cold tolerant as 13-17 month-old Hereford cattle (Mooring and Samuel 1998). House Rock Valley bison hair is more similar to *Bison* (Peters and Slen 1964; confirmed by Holton pers. comm. 2013), yet is less dense in fibers per unit area and fiber length (Peters and Slen 1964).

Other phenotypes are obvious, such as the color of the hair, absence of the hump in cattle, and the shortened or lack of horns in most cattle, the exceptions being the Texas Longhorn and the Scottish Highland. These differences in the hump and horns are also apparent in the skeletal morphology (Skinner and Kaisen 1947; McDonald 1981; Balkwill and Cumbaa 1992). The hump is a result of elongated spinal processes of *Bison*, which the House Rock Valley bison have (as pictured in Minard 2010; Holton pers. comm. 2013), used to support the mass of the head, similar to a suspension bridge (Guthrie 1990). Phenotypically the House Rock Valley animals are bison (Holton pers. comm. 2013).

Climate and Weather Hardiness of *Bison* and *Bos*

Over the past 100 years or so, the House Rock Valley bison herd has continually been purified to *Bison* by the introduction of pure *Bison* males for breeding. However, C.J. Jones's priority with the House Rock Valley bison was to create a hybrid of bison and cattle, known as cattalo, to increase hybrid vigor in an animal that could tolerate extreme climates (as demonstrated in Table 4) (Christopherson et al. 1978; Christopherson 1979). Cattalo produce more meat with a smaller demand for quality vegetation than cattle alone. The House Rock Valley bison have adapted to their surroundings and over time, with the introduction of pure

Bison, also have the same hair structure as pure *Bison*. *Bison* are almost 4-and-a-half fold more apt to survive extreme weather than cattle as evidenced in Table 4, which was compiled after the early October 2013 Blizzard Atlas that affected western South Dakota, western Nebraska, and eastern Wyoming.

Table 4. October 4-5, 2013 Blizzard Atlas South Dakota livestock deaths. Data gathered from the (SDAIB 2013) for cattle, the (USDA 2009) for bison, and (Gordon 2013) for deaths.

Bovid Species	Confirmed Animal Deaths	Animal Census	Percent Mortality
Bos taurus (Beef cattle)	17,795	*3,850,000	0.46%
Bison bison (Bison)	40	38,701	0.10%

*value is approximate

However, Jones's experiment was a failure at the beginning because of high birth mortality and sterility in half the yield (Dary 1974). This mortality rate is also supported by another report that states only female hybrids of a maternal bison and a paternal cattle will survive; male hybrid offspring are sterile, and, thus, not fit for survival (Meagher 1986). Maternal cattle and paternal bison pairings result in death of both the mother and calf from excessive amniotic fluid (Meagher 1986). However, if the cattalo cows have an adequate number of pure bison or pure cattle bulls available for breeding, a sustainable herd may continue to populate.

South Dakota census of livestock is statewide, whereas the deaths from Blizzard Atlas were concentrated in the western half of the state. Note that the majority of the beef cattle and most of the bison do reside in the western half of the state (D. Carter Executive Director of National Bison Association pers. comm. 2013). The cattle are designated as beef cattle because dairy cattle were excluded from this analysis because dairy cows were not greatly affected by Blizzard Atlas because they tend to live in barns, although beef cattle are primarily, if not completely, outside in a pasture year-round. The majority of the beef cattle died from congestive heart failure caused by hypothermia (SDAIB 2013), most likely due to their single layered coat structure. The House Rock Valley bison herd today has sufficient percentages of bison to be as hardy as the privately owned bison in South Dakota bison ranches, which inevitably also have cattle introgression in their genes (Boyd 2003). As an aside, during blizzard and blizzard-like conditions, *Bison* stand facing the wind whereas cattle face away from the wind (Hornaday 1889). This can cause freezing in the cattle's anal region, most often fatally.

Grazing Behaviors

Bison bison and *Bos taurus* also differ in their grazing behaviors. The primary cattle that are referred to here are grass-fed free-ranging cattle, not corn-fed feedlot cattle. *Bos* and *Bison* both have 4-chambered stomachs, regurgitate their food, and chew the cud for additional digestion of the bolus. They obtain the vegetation in the same manor of grazing the tops of older grasses, sedges, and forbs but both prefer new growth vegetation (Biondini et al. 1999). However, grazing strategies vary greatly from cattle to bison. *Bison* prefer to graze on a time minimization strategy; in contrast, cattle graze on an energy maximization strategy (Plumb and Dodd 1993; Bergman and Fryxell 2001). Basically, bison eat what they eat in a short amount of time and move on to the next location in a gregarious setting. Cattle do the opposite, along with sheep, red deer, and goats, and stay in a location for an extended amount of time and eat the majority of the biomass available.

In the cattle strategy, each animal requires a larger area to consume the biomass around them, spreading out the herd, and losing the gregariousness characteristics of an ungulate (Bergman and Fryxell 2001). The advantages of the time minimization strategy include decreased time of insect harassment, daily foraging times that do not suffer during breeding season, social behavior interactions, and, lastly, reduced time foraging increases the chance of survival because of less available predation time (Bergman and Fryxell 2001). These 2 different grazing strategies also influence some nongrazing behaviors, including long- and short-range migration, which affects trampling of vegetation that affects forage selection (Savory and Butterfield 1999).

Forage selection among *Bison* and *Bos* traditionally has been observed to be similar, with a consumption of between 80 and 90% of grasses in their diet, see Figure 22 (Wagner 1978). Other studies have found *Bison* to be more generalistic, depending on the environment and climate. Meagher (1973) found that Yellowstone National Park bison consumed forbs and browse throughout the year and up to 56% of their winter diets contained sedges (Meagher 1973: 91). In Cannon's study (2001), he reported that 2 bison herds in Alaska, one living in grassland (Farewell herd) and the other in riverine valleys adjacent to mountain passes (Delta herd), varied dramatically in forage selectivity. The Farewell herd consumed grasses and sedges through the winter with browse consisting of only 1% of their diet (Campbell 1983; Cannon 2001). The Delta herd, however, primarily ate river bar grasses and farmers' barley, horsetails, and other browse (Gipson and McKendrick 1981; Cannon 2001). Other dietary variations occur during the summer, bison have been documented to have a diet of 50% willow and 50% graminoid (Miquelle 1985; Cannon 2001). During the winter, bison diet can be as much as 75% browse and as little as 25% graminoid (Miquelle 1985; Cannon 2001).

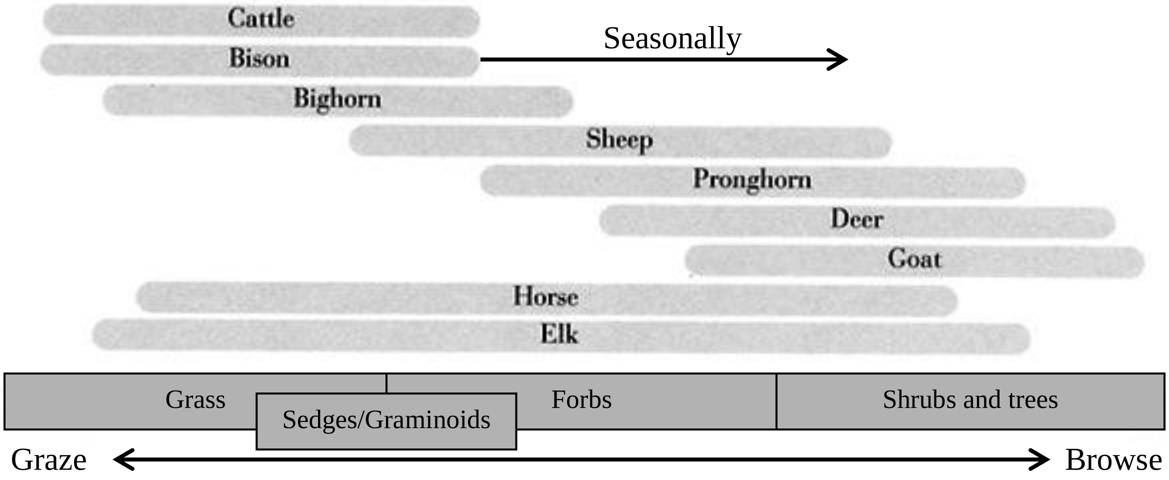


Figure 22. Idealized forage selectivity among North American wild and domestic herbivores (modified from (Meagher 1973; Wagner 1978; Cannon 2001)).

Nongrazing Behaviors

In addition to grazing behaviors, bison and cattle differ in nongrazing behaviors, including 1) migration, 2) grooming via self-scratching, rubbing, oral grooming (licking), and most importantly, 3) wallowing.

Migration. The key difference in migration between *Bison* and *Bos* is that bison do migrate while cattle do not, unless they are herded. Migrations in bison can be a long-range seasonal move, a permanent relocation due to inclement conditions, or a recolonization of a location due to favorable conditions (Meagher 1973; Meagher 1986; Cannon 2001). Seasonal migrations from winter and summer areas are included in the calculations for home ranges. However, in the montane west, migration is not the same as the Great Plains. For the mountainous west, migration may be just an elevational shift on the mountainside (Van Vuren and Bray 1986), rather than a thousand-kilometer trek north or south. This elevational range shift from one biome to another replicates the latitudinal shift of the Great Plains.

Short-range migrations within home ranges of animals are important and always in flux based on herd numbers, environmental conditions, and health of the vegetation. Henry Mountains, nearly 200 km north-northeast of the HRVWA, also have a bison herd. This bison herd is the closest public to the House Rock Valley bison herd with a similar geographic, environmental, and herd setting. The Henry Mountain bison herd consists of about 300 animals (extrapolated from Van Vuren and Bray 1986) and their home range is approximately 300 km^2. The House Rock Valley bison herd summer home range on the Kaibab Plateau is approximately 300 km^2 and the winter birthing home range in HRVWA is 150 km^2 for a total of approximately 450 km^2 (digitized maps and extrapolated from (Larson et al. 2009)).

Grooming. Grooming is essential for many mammals for cleanliness and social interaction (Mooring and Samuel 1998). Three main types of grooming exist for both *Bison* and *Bos*. First, the shared types include 1) self-scratching via hind foot and horns to their own body for removal of ectoparasites and other irritants, 2) rubbing their bodies against foreign objects, and 3) oral grooming by using their tongue to lick themselves. Both cattle and bison exhibit these traits, most notably rubbing, throughout the year with increased frequency during the months of October and November primarily because of the larval stages of winter ticks (Mooring and Samuel 1998). The difference, however, between bison and cattle, is that cattle calves have been shown to suffer loss in weight gain between 10 and 44 kg per year due to blood loss and tick-induced anorexia, whereas, bison calves do not suffer to such extremes (Mooring and Samuel 1998).

Yet bison, for their large size, do not have many ectoparasites (n=133) on average; 4 times less (n=540) than white-tailed deer (*Odocoileus virginiana*), 9 times less (n=1200) than elk

(*Cervus elaphas*), and up to 278 times (n=37,070) less than moose (*Alces alces*) (Mooring and Samuel 1998). Considering bison-human interactions and potential health hazards, having fewer parasites associated with bison is critical (Wright 1998). Another major grooming/nongrazing behavior that *Bison* exhibit that assists with ridding of ectoparasites is wallowing.

Wallowing. *Bison* wallowing is distinct from not only cattle but also the rest of the oxen subfamily, Bovinae (Reinhardt 1985; Mooring and Samuel 1998; Coppedge and Shaw 2000; McMillan et al. 2000; McMillan et al. 2011). Wallowing is a prominent habit of males during rut but is observed throughout the year by males and females of all ages including calves (Mooring and Samuel 1998). Wallows provides a benefit not only to bison as a dusting to inhibit pest colonization on the bison's body (Mooring and Samuel 1998) but also creates spatially heterogeneous microhabitats that contribute to other taxa's survival, including vegetation, amphibians, birds, and invertebrates (Coppedge et al. 1999; Knapp et al. 1999; Coppedge and Shaw 2000; Gerlanc and Kaufman 2003; McMillan et al. 2011). In fact, immediately adjacent to the bare ground of the wallows, and up to 2 meters out from the perimeter, known as the edge, there is more diversity and abundance of vegetation than within the whole ecosystem (McMillan et al. 2011). Rainwater is often pooled in wallows and produces ephemeral wetlands over extended periods during the spring because of the compacted soil. However, during the summer, only drought resistant plants are support (Knapp et al. 1999).

These wallows either remain as bare soil or vegetate, depending on the revisitation frequency of *Bison* (Knapp et al. 1999; Bergman and Fryxell 2001). The landscapes of many ecosystems have coevolved with wallows for tens of thousands of years and the lack of wallows degrades the integrity and infrastructure of an ecosystem at a large and small scale (Reinhardt

1985; Knapp et al. 1999; McMillan et al. 2011). Relic wallows still exist in many areas of the plains where bison have not revisited in that last 140 years.

Ecological Significance of *Bison*

Bison are a keystone species of the West and, as such, increase habitat heterogeneity and alter a broad array of plant, community, and ecosystem processes (Fahnestock and Knapp 1994; Knapp et al. 1999). *Bison*, along with fire, reduce aboveground dead biomass and convert it to nutrients, by ruminating, to be absorbed by the ground. *Bison* grazing affects the quality of plant litter recycled into the soil by increasing the plant uptake of nutrients, including nitrogen (Fahnestock and Knapp 1994; Knapp et al. 1999). The time minimization foraging strategy contributes to the temporal and spatial complexities of bison maintenance of the biotic diversity (Knapp et al. 1999; Bergman and Fryxell 2001). The abundance and richness of annual forbs and the spatial heterogeneity of biomass and cover is higher in sites with bison than in sites with cattle (Knapp et al. 1999). *Bison* graze open grasslands, whereas *Bos* graze both woodlands and grasslands opportunistically (Knapp et al. 1999).

The decease of *Bison* by natural causes, when not removed or disturbed from the premises, releases plentiful quantities of nitrogen rich fluids into the immediate locality because of decomposition. An adult *Bison*, greater than 800 kg, usually kill neighboring and underlying plants (Knapp et al. 1999) because of the high concentrations of nitrogen a but this is only an initial response. Over 3 years, these *Bison* death sites become highly fertile up to 2 and a half meters away from the origin (Knapp et al. 1999). The highly fertile regions then produce up to 3 times the aboveground vegetation compared to the adjacent undisturbed areas (Knapp et al. 1999).

The carcasses of *Bison*, however, rarely go undisturbed as described in the experiment (Knapp et al. 1999), where the carcass was purposefully protected to observe and test the vegetational effects. For example, bison remains, including an upper right second premolar and a horn fragment, have been found in a fossil California condor (*Gymnogyps californianus*) roost in Battleship Rock and Sandblast Cave (this study, sites #8 and #51, respectively), indicating that *Bison* on the Kaibab Plateau may provide an additional natural source of carrion for condor conservation (Emslie 1987). Not only are scavenged *Bison* remains in association with the condor nests but so are other large mammals (DeSaussure 1956; Emslie 1987). While *Bison* may provide food for the California condor it may also provide a food source for other predators as well. To help regulate the population of *Bison* naturally, rare and endangered predator species native to Arizona such as the grizzly bear (*Ursus arctos*), jaguar (*Felis onca*), mountain lion (*Puma concolor*), jaguarundi (*Puma yagouarandi*), and the Mexican wolf (*Canis lupus*) could be reintroduced (Hoffmeister 1986: 7–8).

Case Studies of Bison Conservation Biology and Applied Paleozoology

Lyman (2006: 12) states that “an organism may disappear from an area and reappear later; its abundance may increase or decrease only to decrease or increase at a later date; or individuals may shrink or grow larger.” In doing so, Lyman (2006) emphasizes that it is only through the study of interdisciplinary paleozoology that observations of morphometric, nativity, and abundance changes may be observed through deep time. Behnke, Scoones, and Kerven (1993) who claim ecology is devoid of equilibrium and that it should be considered a natural kinetic process at all times further support this. Often, paleozoological data reveal preanthropogenic patterns that differ from historical or anthropogenic studies, as “natural processes” (Lyman 2006).

Banff National Park personnel in Alberta, Canada were interested in releasing *Bison* into their park boundaries but needed to determine whether bison were native, exotic, or a recolonizing species. Paleozoological data supported that *Bison* had been in the area in the last 10,000 years; thus, bison were acceptable to reintroduce and manage within the study area, even though only fossil adult males were preserved in the Alberta, Canada paleozoological record (Lyman 2006). Banff National Park personnel decided to also include the addition of females to build a sustainable herd structure.

Cannon (2001) uses a multidisciplinary approach of prehistoric remains to understand the ecology, biology, and occurrence of bison in the Greater Yellowstone Area. In Cannon's case, the foundation of knowing when and where bison occur had already been established, whereas within the GGC, the spatial and temporal extent of bison in the past is poorly known. Cannon (2001) states that using paleontological, archaeological, historical, and modern research not only contributes to the analysis of bison abundance in the past but also contributes to the study and implementation of modern bison management.

Stronen and Paquet (2013) suggest that where hybrids have filled an empty ecological niche of one or both of the parent taxa focus should be directed towards the ecological role for the community structure and for a natural restoration and management of the community. Much of what we know about bison on the CP is based on historic and modern studies. While these are invaluable sources, they are incomplete and do not expose the depths of time. Archeological studies provide a pre-European condition of the study area; however, these still do not address the depth of time issue. Paleontological fossil and subfossil data provide adaptations to climatic conditions through time including migrations and ecological reconstructions (Cannon 2001). Each discipline together provides paleozoological data sufficient for informed decisions on management of contemporary bison herds, such as the House Rock Valley bison herd. Knowledge of prehistorical data allows for the analysis to consider if a species is exotic or merely a recolonizing species following extirpation caused by anthropogenic or climatic factors.

CHAPTER 5

CONCLUSION

"How many legs does a dog have if you call the tail a leg? Four. Calling a tail a leg doesn't make it a leg."

―Abraham Lincoln

Wildlife Management Implications

Much of what we know about bison on the CP is based on historic and modern studies. While these are invaluable sources, they are incomplete and do not expose the depths of time. Archeological studies provide a pre-European condition of the study area; however, they still do not address the depth of time issue. Paleontological fossil and subfossil data provide evidence of adaptations to climatic conditions through time including migrations and ecological reconstructions. Each discipline together provides data important for informed decisions on the management of contemporary bison herds, like the House Rock Valley bison herd.

The direct impact of this study is the production the first comprehensive review of Holocene *Bison* on the CP. In addition, the geographic range of fossil *Bison* can be extended to include the CP. Currently, *Bison* is omitted from the CP; though, their remains are found there.

Rangeland and Natural Resource Management

There are natural resource management and rangeland conservation implications that are also directly influenced by the results of this thesis. Bison have been and are now ecological keystone species in rangelands of the west (Knapp et al. 1999) and, based on fossil and subfossil remains bison are native to the area. Conservation issues that GRCA is experiencing may be alleviated by not extirpating the bison, which is expensive ‘financially’ and ‘resourcefully’ (Reimondo 2012).

R. Lee Lyman (2006) once said, “Whether a taxon is native or exotic is but one side of the coin, the side concerning determinations of which taxa to allow in an area. Some exotic taxa are beneficial or ecologically benign. The other side of the coin concerns determinations of which taxa should be denied access to an area.” This House Rock Valley bison population, in particular, should be viewed as evolutionary significant units where they are geographically separated from any other cattalo, cattle, and bison herds and where they have genetic differentiation (Conner and Hartl 2004; Douglas et al. 2011; Derr et al. 2012).

Generic Argument of *Bison* and *Bos*

Taxonomically, through skeletal morphology, synonymizing *Bison* with *Bos* would be irresponsible because the 2 genera are distinguishable using both cranial and postcranial characters (Skinner and Kaisen 1947; Balkwill and Cumbaa 1992). Biologically, however, *Bison* and *Bos* can hybridize but only successfully in one scenario; only a male *Bos* and a female *Bison* may mate to create offspring (Meagher 1986). If the situation is reversed, the female and calf will die from an oversize calf breaching during birth. Thus, because of the breeding situation, cattle and bison should be considered different species.

Furthermore, synonymizing *Bison* with *Bos* ecologically, at this point, is also irresponsible because the 2 genera are ecologically distinct through grazing and nongrazing behaviors. Additionally, genetically speaking, the Derr Lab suggests that the genus of *Bison* may be invalid and that *Bos* is more accurate so that the American Plains bison should be “*Bos bison bison*.” Conservationally, the House Rock Valley bison herd serves the ecological role of *Bison*, yet remains to be culturally significant with ties to Theodore Roosevelt (Stronen and Paquet

2013). The House Rock Valley bison herd has just as much history of conservation and preservation as the Yellowstone National Park herd. Moreover, the area is devoid of cattle and bison, and, thus is devoid of an ecological role that must be filled. What better herd than the one commissioned by Theodore Roosevelt?

Closing Remarks

These methods of using the online databases and ArcGIS together with traditional archaeology and paleontology to map the potential *Bison* coverage can be applied to any animal, modern or fossil, with any temporal scale for all of the 27 National Parks or National Monuments on the Colorado Plateau.

This study concludes that bison are native to the CP, GRCA, and KNF during the Historic, Protohistoric, Prehistoric, and Pre-anthropogenic periods. The remains of bison on the CP suggest the herd structure was likely small groups of young and old males and females that seasonally ‘roamed’ vertically on mountain slopes rather than latitudinally like their Plains relatives. However, during the Preformative and Archaic Periods, bison were not likely sustaining herds on the CP.

The House Rock Valley bison fulfill the ecological role of pure bison for reducing fire load through grazing on the Kaibab Plateau and North Rim of GRCA (Knapp et al. 1999). In addition to reducing the fire load, grazing increases the nutrient levels in the soil, and wallowing increases the spatial heterogeneity and biodiversity of the immediate area (Coppedge et al. 1999; Knapp et al. 1999; Coppedge and Shaw 2000; Gerlanc and Kaufman 2003; McMillan et al. 2011).

Bison are native to the CP, GRCA, KNF, thus, conservation efforts and management plans are recommended. According to the National Park Service management handbook, culturally significant natural resources should also be protected. The long history, as early as 1873 AD, of developing an American-bred beef lineage with descendants of bison is culturally, historically, and ecologically important to protect the animals and to teach the public about the effort to conserve bison from extinction. Additionally, it is recommended to allow the *Bison* to continue their seasonal range migration cycle that they have naturally established from HRVWA, through the KNF, and onto the North Rim of GRCA.

REFERENCES

ABA. 2014. American Beefalo Association. Available from: http://americanbeefalo.org/

Agenbroad LD, Haynes CV. 1975. Bison Bison Remains at Murray Springs, Arizona. Kiva 40:309–313.

Agenbroad LD. 2009. Mammuthus exilis from the California Channel Islands: Height, Mass, and Geologic Age. In: Damiani CC, Garcelon DK, editors. Proceedings of the 7th California Islands Symposium. Arcata, California: Institute for Wildlife Studies.

Ahlstrom RVN, Purcell DE, Zyniecki M, Gilpin DA, Newton VL. 1993. An archaeological overview of Grand Canyon National Park. Grand Canyon, AZ.

Aikens CM. 1967. Excavations at Snake Rock Village and the Beaver River No. 2 site. Univ. Utah Anthropol. Pap. 87.

Anderson E. 1966. Animal Remains.Lister R, editor. Contrib. to Mesa Verde Archaeol. III site 866 Cult. Seq. four villages Far View Group, Mesa Verde Natl. Park. Color. University:113–114.

Anderson RS, Betancourt JL, Mead JI, Hevly RH, Adam DP. 2000. Middle- and late-Wisconsin paleobotanic and paleoclimatic records from the southern Colorado Plateau, USA. Palaeogeogr. Palaeoclimatol. Palaeoecol. [Internet] 155:31–57. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0031018299000930

AZGFD. 2013. California Condor. Arizona Game Fish Dep. [Internet]. Available from: http://www.azgfd.gov/w_c/california_condor.shtml

Balkwill DM, Cumbaa SL. 1992. A Guide to the Identification of Postcranial Bones of Bos taurus and Bison bison. Syllogeus 71:277.

Barnosky AD, IB286 Working Group. 2012. Prelude to the anthropocene: two newly-defined North American Land Mammal Ages. In: Journal of Vertebrate Paleontology: Program and Abstracts. p. 60. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:PRELUDE+TO+THE+ANTHROPOCENE:+TWO+NEWLY-DEFINED+NORTH+AMERICAN+LAND-MAMMAL+AGES#0

Behnke RH, Scoones I, Kerven C. 1993. Range ecology at disequilibrium: new models of natural variability and pastoral adaptation in Africa's savannas. London, England: ODI.

Bell CJ, Lundelius Jr. E, Barnosky AD, Graham RW, Lindsay EH, Ruez Jr. DR, Semken Jr. H, Webb SD, Zakrsewski RJ. 2004. The Blancan, Irvingtonian, and Rancholabrean Mammal Ages. In: Woodburne MO, editor. Late Cretaceous and Cenozoic mammals of North

America: Biostratigraphy and Geochronology. New York, NY: Columbia University Press. p. 232–314.

Bergman C, Fryxell J. 2001. Ungulate foraging strategies: energy maximizing or time minimizing? J. Anim. … [Internet] 70:289–300. Available from: <Go to ISI>://000169014300011

Betancourt JL. 1990. Late quaternary biogeography of the Colorado Plateau. In: Betancourt JL, Van Devender TR, Martin PS, editors. Packrat middens: The last 40,000 years of biotic change. Tucson, Arizona: University of Arizona Press. p. 259–293. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Late+Quaternary+Biogeography+of+the+Colorado+Plateau#0

Billat SE. 1985. A study of Fremont subsistence at the Smoking Pipe site. Brigham Young University.

Biondini ME, Steuter AA, Hamilton RG. 1999. Bison use of fire-managed remnant prairies. J. Range Manag. [Internet] 52:454–461. Available from: https://digitalcommons.library.arizona.edu/objectviewer?o=http://jrm.library.arizona.edu/Volume52/Number5/azu_jrm_v52_n5_454_461_m.pdf

Blakey RC, Ranney W. 2008. Ancient Landscapes of the Colorado Plateau: (Grand Canyon). Grand Canyon, AZ: Grand Canyon Association.

Blakey RC. 2009. Paleogeography and Geologic History of the Western Ancestral Rocky Mountains, Pennsylvanian-Permian, Southern Rocky Mountains and Colorado Plateau. :222–264. Available from: http://archives.datapages.com/data/rocky-mtn-geologist-pubs/data/005/005001/222_rmag-bk0050222.htm

Boyd D, Gates C. 2006. A brief review of the status of plains bison in North America. J. West [Internet] 45:15–21. Available from: http://buffalofieldcampaign.org/legal/esacitations/boydreviewstatus.pdf

Boyd D. 2003. Conservation of North American bison: status and recommendations. Available from: http://www.bisonandroads.com/docs/conservationstatusnabisonthesisboyd2003.pdf

Broecker W. 2000. Abrupt climate change: causal constraints provided by the paleoclimate record. Earth-Science Rev. [Internet] 51:137–154. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0012825200000192

Broughton JM, Byers D a., Bryson R a., Eckerle W, Madsen DB. 2008. Did climatic seasonality control late Quaternary artiodactyl densities in western North America? Quat. Sci. Rev. [Internet] 27:1916–1937. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0277379108001704

Campbell BH and MH. 1983. Winter diets and habitat use of Alaska bison after wildfire. Wildl. Soc. Bull. 11:16–21.

Cannon K. 2001. What the past can provide: contribution of prehistoric bison studies to modern bison management. Gt. Plains Res. A J. Nat. Soc. Sci. [Internet] 11:145–174. Available from: http://digitalcommons.unl.edu/greatplainsresearch/540/

Cantino PD, De Queiroz K. 2010. International Code of Phylogenetic Nomenclature. PhyloCode Ohio Univ. 4:102.

Christopherson R, Hudson R, Richmond R. 1978. Comparative Winter Bioenergetics of American Bison, Yak, Scottish Highland nad Hereford Calves. Acta Theriol. (Warsz). [Internet] 23:49–54. Available from: http://rcin.org.pl/ibs/Content/10506/BI002_11474_Cz-40-2_Acta-T23-nr2-49-54_o.pdf

Christopherson R. 1979. Seasonal energy expenditures and thermoregulatory responses of bison and cattle. Can. J. … [Internet] 59:611–617. Available from: http://pubs.aic.ca/doi/abs/10.4141/cjas79-077

Clark B. 2014. Earth Point: Township and Range - Public Land Survey System on Google Earth. Available from: http://www.earthpoint.us/Townships.aspx

Coats LL, Cole KL, Mead JI. 2008. 50,000 years of vegetation and climate history on the Colorado Plateau, Utah and Arizona, USA. Quat. Res. [Internet] 70:322–338. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0033589408000562

Cohen K, Finney S, Gibbard P, Fan J. 2013. The ICS International Chronostratigraphic Chart. Episodes [Internet] 36:199–204. Available from: http://www.episodes.co.in/contents/2013/september/p199-204.pdf

Cole K. 1982. Late quaternary zonation of vegetation in the eastern grand canyon. Science [Internet] 217:1142–5. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17740971

Cole K. 1985. Past Rates of Change, Species Richness, and a Model of Vegetational Inertia in the Grand Canyon, Arizona. Am. Nat. [Internet] 125:289. Available from: http://www.journals.uchicago.edu/doi/abs/10.1086/284341

Cole KL. 2010. Vegetation response to early holocene warming as an analog for current and future changes. Conserv. Biol. [Internet] 24:29–37. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20121839

Conner JK, Hartl DL. 2004. A primer of ecological genetics. Sinauer Associates.

Cook CW. 1980. Faunal analysis from five Utah Valley sites: a test of a subsistence model from the Sevier Fremont Area. Brigham Young University.

Coppedge BR, Fuhlendorf SD, Engle DM, Carter BJ, Shaw JH. 1999. Grassland soil depressions: relict bison wallows or inherent landscape heterogeneity? Am. Midl. Nat. [Internet] 142:382–392. Available from: http://www.bioone.org/doi/abs/10.1674/0003-0031(1999)142[0382:GSDRBW]2.0.CO;2

Coppedge BR, Shaw JH. 2000. American bison Bison bison wallowing behavior and wallow formation on tallgrass prairie. Acta Theriol. (Warsz). [Internet] 45:103–110. Available from: http://rcin.org.pl/Content/12994/BI002_27023_Cz-40-2_Acta-T45-nr10-103-110_o.pdf

Creasman S, Scott LJ. 1987. Texas Creek overlook: evidence for late Fremont (post A.D.1200) occupation in northwest Colorado. Southwest. Lore 53:1–16.

Cronin M a, MacNeil MD, Vu N, Leesburg V, Blackburn HD, Derr JN. 2013. Genetic variation and differentiation of bison (Bison bison) subspecies and cattle (Bos taurus) breeds and subspecies. J. Hered. [Internet] 104:500–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/23667052

Dary DA. 1974. The Buffalo Book: The Full Saga of the American animal. Chicago, Illinois: The Swallow Press.

Derr JN, Hedrick PW, Halbert ND, Plough L, Dobson LK, King J, Duncan C, Hunter DL, Cohen ND, Hedgecock D. 2012. Phenotypic effects of cattle mitochondrial DNA in American bison. Conserv. Biol. [Internet] 26:1130–6. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22862781

DeSaussure R. 1956. Remains of the California condor in Arizona caves. Plateau [Internet] 29:44–45. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:remains+of+the+california+condor+in+arizona+caves#3

Douglas KC, Halbert ND, Kolenda C, Childers C, Hunter DL, Derr JN. 2011. Complete mitochondrial DNA sequence analysis of Bison bison and bison–cattle hybrids: Function and phylogeny. Mitochondrion [Internet] 11:166–175. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20870040

Downum CE, Cummings LS, Puseman K, Sorrell DH, Vance MM. 2011. Archaeological Excavations at Site B:16:105, Grand Canyon National Park. Flagstaff, AZ.

Dratch PA, Gogan PJP. 2010. Bison conservation initiative: bison conservation genetics workshop: report and recommendations.

Emslie S. 1988. Vertebrate paleontology and taphonomy of caves in Grand Canyon, Arizona. Natl. Geogr. Res. [Internet] 4:128–142. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Vertebrate+Paleontology+and+Taphonomy+of+Caves+in+Grand+Canyon,+Arizona#0

Emslie SD. 1987. Age and diet of fossil california condors in grand canyon, Arizona. Science [Internet] 237:768–70. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17751565

Fahnestock J, Knapp A. 1994. Plant responses to selective grazing by bison: interactions between light, herbivory and water stress. Vegetatio [Internet] 115:123–131. Available from: http://www.springerlink.com/content/q66386777558616w/

Figueroa AP-, Antao T, Coombs JA, Luikart G. 2010. Conserving Genetic Diversity in Yellowstone Bison: Effects of population fluctuations and variance in male reproductive success in age structured populations. Mammoth Hot Springs, Wyoming.

Finan TJ, West CT, Austin D, McGuire T. 2002. Processes of adaptation to climate cariability: a case study from the US Southwest. Clim. Res. 21:299–310.

Flores D. 1991. Bison ecology and bison diplomacy: the southern plains from 1800 to 1850. J. Am. Hist. [Internet] 78:465–485. Available from: http://www.jstor.org/stable/2079530

Flowers RM, Wernicke BP, Farley K a. 2008. Unroofing, incision, and uplift history of the southwestern Colorado Plateau from apatite (U-Th)/He thermochronometry. Geol. Soc. Am. Bull. [Internet] 120:571–587. Available from: http://gsabulletin.gsapubs.org/cgi/doi/10.1130/B26231.1

Fowler DD, Madsen DB, Hattori EM. 1973. Prehistory of southeastern Nevada. Desert Res. Institute, Soc. Sci. Humanit. Tech. Rep. Ser. 6.

Frison GC. 1978. Prehistoric hunters of the high plains. New York, NY: Academic Press.

Fuller W. 1960. Behaviour and social organization of the wild bison of Wood Buffalo National Park, Canada. Arctic [Internet]:2–19. Available from: http://arctic.journalhosting.ucalgary.ca/arctic/index.php/arctic/article/view/3685

Gates C, Freese C, Gogan P, Kotzman M. 2010. American bison: status survey and conservation guidelines 2010. Available from: http://books.google.com/books?hl=en&lr=&id=koUrGx-i2ucC&oi=fnd&pg=PR11&dq=American+Bison:+Status+Survey+and+Conservation+Guidelines+2010&ots=VULd4kVhwW&sig=pDW2JqFm4TLQYwTlxA_A10uOhHU

Gerlanc N, Kaufman G. 2003. Use of bison wallows by anurans on Konza Prairie. Am. Midl. Nat. [Internet] 150:158–168. Available from: http://www.bioone.org/doi/abs/10.1674/0003-0031(2003)150%5B0158:UOBWBA%5D2.0.CO%3B2

Gillette DD, Madsen DB. 1992. The short-faced bear Arctodus simus from the late Quaternary in the Wasatch Mountains of central Utah. J. Vertebr. Paleontol. 12:107–112.

Gillin J, Allen GM. 1941. Archaeological investigations in central Utah. Pap. Peabody Museum Archaeol. Ethnol. 17:1–46.

Gipson PS, McKendrick JD. 1981. Bison depredation of grain fields in interior Alaska. Fifth Gt. Plains Wildl. Damage Control Work. 5:116–121.

Gordon K. 2013. The Aftermath. Drovers Cattle Netw. [Internet]. Available from: http://www.cattlenetwork.com/drovers/The-Aftermath-235623771.html

Grayson D, Livingston S. 1993. Missing mammals on Great Basin mountains: Holocene extinctions and inadequate knowledge. Conserv. Biol. [Internet] 7:527–532. Available from: http://onlinelibrary.wiley.com/doi/10.1046/j.1523-1739.1993.07030527.x/full

Grayson D. 2006. Holocene bison in the Great Basin, western USA. The Holocene [Internet] 16:913–925. Available from: http://hol.sagepub.com/cgi/doi/10.1191/0959683606hol982fa

Guthrie RD. 1990. Frozen fauna of the Mammoth Steppe: the story of Blue Babe. Chicago, Illinois: University of Chicago Press.

Halbert N, Derr JN. 2008. Patterns of genetic variation in US federal bison herds. Mol. Ecol. [Internet] 17:4963–4977. Available from: http://www.ncbi.nlm.nih.gov/pubmed/19017265

Halbert N. 2003. The utilization of genetic markers to resolve modern management issues in historic bison populations: implications for species conservation. Available from: http://repository.tamu.edu/handle/1969.1/1415

Hansen RM. 1980. Late Pleistocene plant fragments in the dungs of herbivores at Cowboy Cave in Cowboy Cave. Univ. Utah Anthropol. Pap. 104:179–189.

Harington CR, Euler R. 1984. Ungulate remains from Stanton's Cave: an identification list. In: Euler RC, editor. The Archaeology, Geology, and Paleobiology of Stanton's Cave: Grand Canyon National Park, Arizona. Grand Canyon, AZ: Grand Canyon Natural History Association. p. 69–75. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Ungulate+remains+from+Stanton's+Cave:+An+identification+list#0

Harris AH. 1993. Quaternary vertebrates of New Mexico. New Mex. Museum Nat. Hist. Sci. Bull. 2:179–195.

Haury EW. 1940. Excavations in the Forestdale Valley, east-central Arizona. Univ. Arizona Bull. Soc. Sci. Bull. 12.

Haury EW. 1965. Food: Animal. In: Gladwin HS, Haury EW, Sayles EB, Gladwin N, editors. Excavations at Snaketown: Material Culture. Tucson, Arizona: University of Arizona Press. p. 156–158.

Hay O. 1927. On Pleistocene Geology of Western Region of North America and remains of vertebrates occurring in it: Arizona. :129–137.

Hayes AC, Lancaster JA. 1975. Badger House community, Mesa Verde National Park. U.S. Dep. Inter. Natl. Park Serv. Wetherill Mesa Stud. Publ. Archeol. 7E.

Heaton TH. 1988. Bears and man at Porcupine Cave, Western Uinta Mountains, Utah. Curr. Res. Pleistocene 5:71–73.

Heller MM. 1976. Zooarchaeology of Tularosa Cave, Catron County, New Mexico. University of Texas at El Paso.

Hendrick PW. 2009. Conservation Genetics and North American bison (Bison bison). J. Hered. 100:411–420.

Hoffmeister D. 1986. Mammals of Arizona. Univ. Arizona Press Arizona Game Fish Dep.:5, 7, 8, and 559–560.

Hornaday WT. 1889. The extermination of the American Bison.

Huffer DJ. 2013. A spatial analysis and zooarchaeological interpretation of archaeological bison remains in the Southwest and the wildlife managment implications for the House Rock Valley bison herd in Grand Canyon National Park, Arizona. The University of Arizona.

Hunter M. 1996. Editorial: Benchmarks for Managing Ecosystems: Are Human Activities Natural? Conserv. Biol. [Internet] 10:695–697. Available from: http://www.jstor.org/stable/2387088

Isenberg A. 1997. The returns of the bison: nostalgia, profit, and preservation. Environ. Hist. Durh. N. C. [Internet]. Available from: http://www.jstor.org/stable/3985507

Jass CN, George CO. 2010. An assessment of the contribution of fossil cave deposits to the Quaternary paleontological record. Quat. Int. [Internet] 217:105–116. Available from: http://linkinghub.elsevier.com/retrieve/pii/S1040618209004066

Jennings JD. 1978. Prehistory of Utah and the eastern Great Basin. Univ. Utah Anthropol. Pap. 98.

Johnson PC. 1974. Mammalian remains from Los Colinas, a Classic Hohokam site in Arizona. Arizona State Museum.

Karlstrom KE, Coblentz D, Dueker K, Ouimet W, Kirby E, Van Wijk J, Schmandt B, Kelley S, Lazear G, Crossey LJ, et al. 2012. Mantle-driven dynamic uplift of the Rocky Mountains and Colorado Plateau and its surface response: Toward a unified hypothesis. Lithosphere [Internet] 4:3–22. Available from: http://lithosphere.gsapubs.org/cgi/doi/10.1130/L150.1

Kent D V., Witte WK. 1993. Slow apparent polar wander for North America in the Late Triassic and large Colorado Plateau rotation. Tectonics [Internet] 12:291–300. Available from: http://doi.wiley.com/10.1029/92TC01966

Knapp AK, Blair JM, Briggs JM, Collins SL, Hartnett DC, Johnson LC, Towne EG, John M, Scott L. 1999. North Keystone Role of Bison in American Tallgrass Prairie Bison increase habitat heterogeneity processes. Bioscience [Internet] 49:39. Available from: http://www.jstor.org/stable/1313492?origin=crossref

Kropf M, Mead JI, Anderson RS. 2007. Dung, diet, and the paleoenvironment of the extinct shrub-ox (Euceratherium collinum) on the Colorado Plateau, USA. Quat. Res. [Internet]

67:143–151. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0033589406001256

Kurtén B, Anderson E. 1980. Pleistocene mammals of North America. New York, NY: Columbia University Press.

Larson A, Henn A, Cultra C, Ray C, Wadsack K, Henn M, Bergamini R, Sisk T, Hutchinson C. 2009. Bison in the Grand Canyon Region : Implications and Recommendations.

Larter N, Nishi J, Ellsworth T, Johnson D. 2003. Observations of Wood Bison Swimming across the Liard River, Northwest Territories, Canada. Arctic [Internet] 56:408–412. Available from: http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=00040843&AN=12025468&h=FGazS%2FVXFFGjulvTaP0xzof7aD7s6vsSipjbsRNTsSiTuVyZTrqstxstqtD3Xooq9WBFSVTmPHP7uiwfAIkH9w%3D%3D&crl=c

Lawrence B. 1951. Mammals Found at the Awatovi Site: Post-cranial Skeletal Characters of Deer, Pronghorn, and Sheep-goat with Notes on Bos and Bison. Pap. Peabody Museum Am. Archaeol. Ethnol. [Internet] 35:43. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Mammals+found+at+the+Awatovi+Site#1

Leonard RDW. 1989. Anasazi faunal exploitation: prehistoric subsistence on northern Black Mesa, Arizona. South. Illinois Univ. Cent. Archaeol. Investig. Occas. Pap. 13.

Lewis PJ, Buchanan B, Johnson E. 2005. Sexing bison metapodials using principal component analysis. Plains Anthropol. 50:1–14.

Lightfoot KG, Feinman GM. 1982. Social differentiation and leadership development in early pithouse villages in the Mogollon region of the American Southwest. Am. Antiq. [Internet] 47:64–86. Available from: http://cat.inist.fr/?aModele=afficheN&cpsidt=12321753

Lindsay E, Tessman N. 1974. Cenozoic vertebrate localities and faunas in Arizona. J. Arizona Acad. Sci. [Internet] 9:3–24. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Cenozoic+Vertebrate+Localities+and+Faunas+in+Arizona#0

Lodge DM, Shrader-Frechette K. 2003. Nonindigenous Species: Ecological Explanation, Environmental Ethics, and Public Policy. Conserv. Biol. [Internet] 17:31–37. Available from: http://doi.wiley.com/10.1046/j.1523-1739.2003.02366.x

Lucas SG, Williamson T, Sobus J. 1988. Late Pleistocene (Rancholabrean) mammals from the Edith Formation, Albuquerque, New Mexico. New Mex. J. Sci. 28:51–58.

Lucias WA, Colville JK. 1980. Osteological analysis of faunal remains. In: Jennings JD, Schroedl AR, Holmer RN, editors. Sudden Shelter. 103rd ed. Salt Lake City, Utah: University of Utah Anthropological Paper. p. 157–170.

Lupo KD, Schmitt DN. 1997. On Late Holocene variability in Bison populations in the northeastern Great Basin. J. Calif. Gt. Basin Anthropol. 19:50–69.

Lyman RL, Cannon KP. 2004. Zooarchaeology and Conservation Biology. Salt Lake City, Utah: The University of Utah Press.

Lyman RL. 2006. Paleozoology in the service of conservation biology. Evol. Anthropol. Issues, News, Rev. [Internet] 15:11–19. Available from: http://doi.wiley.com/10.1002/evan.20083

Madsen DB, Rhode D, Grayson DK, Broughton JM, Livingston SD, Hunt J, Quade J, Schmitt DN, Shaver III MW. 2001. Late Quaternary environmental change in the Bonneville Basin, western USA. Palaeogeogr. Palaeoclimatol. Palaeoecol. 167:243–271.

Malotki E, Wallace H. 2011. Columbian mammoth petroglyphs from the San Juan River near Bluff, Utah, United States. Rock Art Res. [Internet] 28:143–152. Available from: http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=08130426&AN=67047149&h=%2Bp6rfTx2rXiSVF4VQl7Yx0MBFqp4SUX5qns1BMC3CK6oiDLO5cLYAqyz%2FNkNrfENtVVffSZxzhNQ2j58PC7Pxw%3D%3D&crl=c

Martin P. 1987. Late Quaternary extinctions: The promise of TAMS 14 C dating. Nucl. Instruments Methods Phys. Res. Sect. B [Internet] B29:179–186. Available from: http://www.sciencedirect.com/science/article/pii/0168583X87902321

Marwitt JP. 1968. Pharo Village. Univ. Utah Anthropol. Pap. 91.

McClaran MP, Van Devender TR. 1995. The Desert Grassland. University of Arizona Press. Available from: http://books.google.com/books?hl=en&lr=&id=BAlCcnXtXg4C&pgis=1

McDonald J, Lammers G. 2002. Bison antiquus from Kenora, Ontario, and notes on the evolution of North American Holocene Bison. Smithson. Contrib. to Paleobiol. [Internet] 93:83–97. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Bison+antiquus+from+Kenora,+Ontario,+and+Notes+on+the+Evolution+of+North+American+Holocene+Bison#0

McDonald JN. 1981. North American bison: Their classification and evolution. Los Angeles: University of California Press. Available from: http://www.getcited.org/pub/102075856

McKern S. 1988. Archaeological investigation at the Bessie Bottom site (48UT1186): late prehistoric animal procurement in the upper Bear River drainage. Rock Springs, Wyoming.

McMillan B, Pfeiffer K, Kaufman D. 2011. Vegetation responses to an animal-generated disturbance (bison wallows) in tallgrass prairie. Am. Midl. Nat. [Internet] 165:60–73. Available from: http://www.bioone.org/doi/abs/10.1674/0003-0031-165.1.60

McMillan BR, Cottam MR, Kaufman DW. 2000. Wallowing behavior of American bison (Bos bison) in tallgrass prairie: an examination of alternate explanations. Am. Midl. Nat. [Internet] 144:159–167. Available from: http://www.bioone.org/doi/abs/10.1674/0003-0031(2000)144%5B0159:WBOABB%5D2.0.CO%3B2

Mead JI, Agenbroad LD. 1989. Pleistocene dung and the extinct herbivores of the Colorado Plateau, southwestern USA. Cranium [Internet] 6:29–44. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:pleistocene+dung+and+the+extinct+herbivores+of+the+colorado+plateau,+southwestern+USA#1

Mead JI, Agenbroad LD. 1992. Isotope dating of Pleistocene dung deposits from the Colorado Plateau, Arizona and Utah. Radiocarbon [Internet] 34:1–19. Available from: https://journals.uair.arizona.edu/index.php/radiocarbon/article/download/1437/1441

Mead JI, Czaplewski NJ, Agenbroad LD. 2005. Rancholabrean (late Pleistocene) mammals and localities of Arizona. Mesa Southwest Museum Bull. 11:139–180.

Mead JI, Johnson CB. 2004. Bison and Bos from protohistoric and historic localities in the San Rafael Valley, Arizona. Kiva [Internet] 70:183–193. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Bison+and+Bos+from+Protohistoric+AND+HISTORIC+LOCALITIES+IN+THE+SAN+RAFAEL+VALLEY+,+ARIZONA#0

Mead JI, Sharpe SE, Agenbroad LD. 1991. Holocene Bison from Arches National Park, Southeastern Utah. Gt. Basin Nat. 51:336–342.

Mead JI. 2002. Bison of the Grand Canyon Region, Arizona: An Overview Assessment. Flagstaff, AZ. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Bison+of+the+Grand+Canyon+Region,+Arizona:+An+overview+assessment#1

Mead JI. 2004. Canyon dwellers during the Ice Age and Since. Boatman’s Q. Rev. 17:36–38.

Meagher M. 1973. The bison of Yellowstone National Park. Natl. Park Serv. Sci. Monogr. Ser. [Internet] 1:1–161. Available from: http://www.getcited.org/pub/101473029

Meagher M. 1986. Bison bison. Mamm. Species 266:1–8.

Miller WE. 1987. Mammut americanum, Utah’s first record of the American mastodon. J. Paleontol. 61:168–183.

Minard A. 2010. Bison in the Grand Canyon? Four Corners Free. [Internet]. Available from: http://fourcornersfreepress.com/news/2010/021001.htm

Miquelle D. 1985. Food habits and range conditions of bison and sympatric ungulates on the Upper Chita River, Wrangell-Saint Elias National Park and Preserve. Alaska Reg. Res. Resour. Manag. Rep. AR-8.

Montgomery RG, Smith W, Brew JO. 1949. Franciscan Awatovi: the excavation and conjectural reconstruction of a 17th-century Spanish mission establishment at a Hopi Indian town in northeastern Arizona. Report of . Peabody Museum, Harvard University.

Mooring M, Samuel W. 1998. Tick defense strategies in bison: the role of grooming and hair coat. Behaviour [Internet] 135:693–718. Available from: http://www.jstor.org/stable/4535554

Mutschler BFE, Larson EE, Gaskill DL. 1997. Previous section Volume contents The Fate of the Colorado Plateau — A View from the Mantle. In: Friedman JD, Huffman AC, editors. Laccolith Complexes of Southeastern Utah: Time of Emplacement and Tectonic Setting-Workshop Proceedings. Vol. c. U.S. Geological Survey Bulletin 2158. p. 203–222.

O'Hara M. 2008. The Magician of Ridge Ruin: an interpretation of the social, political, and ritual roles represented. In: Beyond Status: Meaning, Metaphor, and Identity in the New World Mortuary Record of the 73rd Annual Meeting. Vancouver, British Columbia: Society for American Archaeology. p. 36.

Olsen SJ. 1960. Post-cranial skeletal characters of Bison and Bos. Pap. Peabody Museum Archaeol. Ethnol. 35:86.

Osborn AJ, Brown J, Burgett G, Cummings LS, Hartley RJ, Vetter S, Waters J, Zalucha T. 1995. Aboriginal adaptations on the Colorado Plateau: A view from the Island-in-the-Sky, Canyonlands National Park, Utah. Midwest Archeol. Cent. Occas. Stud. Anthropol. 33:245–309.

Peters H, Slen S. 1964. Hair coat characteristics of bison, domestic× bison hybrids, cattalo, and certain domestic breeds of beef cattle. Can. J. Anim. Sci. [Internet] 44:48–57. Available from: http://pubs.aic.ca/doi/abs/10.4141/cjas64-009

Plumb G, Dodd J. 1993. Foraging ecology of bison and cattle on a mixed prairie: implications for natural area management. Ecol. Appl. [Internet] 3:631–643. Available from: http://www.jstor.org/stable/10.2307/1942096

Polyak VJ, Asmerom Y, Burns SJ, Lachniet MS. 2012. Climatic backdrop to the terminal Pleistocene extinction of North American mammals. Geology [Internet] 40:1023–1026. Available from: http://geology.gsapubs.org/cgi/doi/10.1130/G33226.1

Polyak VJ, Asmerom Y. 2001. Late Holocene climate and cultural changes in the southwestern United States. Science [Internet] 294:148–51. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11588259

Polziehn R, Strobeck C, Sheraton J, Beech R. 1995. Bovine mtDNA discovered in North American bison populations. Conserv. Biol. [Internet] 9:1638–1643. Available from: http://www.jstor.org/stable/2387208

Polziehn RO, Beech R, Sheraton J, Strobeck C. 1996. Genetic relationships among North American bison populations. Can. J. Zool. [Internet] 74:738–749. Available from: http://www.nrcresearchpress.com/doi/abs/10.1139/z96-084

Powell JW. 1875. Exploration of the Colorado River of the West and its Tributaries: Explored in 1869, 1870, 1871, and 1872. Washington D.C.: U.S. Government Printing Office.

Price M. 2012. Mastering ArcGIS. 5th ed. New York, NY: McGraw Hill.

Pucek Z, Belousova I, Krasinska M, Krasinski ZA, Olech W. 2004. European bison: status survey and conservation action plan. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:European+Bison:+Status+Survey+and+Conservation+Action+Plan#0

De Queiroz K. 2007. Species concepts and species delimitation. Syst. Biol. [Internet] 56:879–86. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18027281

Ranney W. 2012. Carving Grand Canyon. 2nd ed. (Ranney W, editor.). Grand Canyon, AZ: Grand Canyon Association.

Reed E. 1952. The myth of Montezuma’s bison and the type locality of the species. J. Mammal. [Internet] 33:390–393. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:The+myth+of+Montezuma’s+bison+and+the+type+locality+of+species#0

Reimer P, Bard E, Bayliss A. 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. Radiocarbon [Internet] 55:1869–1887. Available from: https://journals.uair.arizona.edu/index.php/radiocarbon/article/view/16947

Reimondo EL. 2012. Ecological impacts and managment implications of introduced bison in the Grand Canyon. Northern Arizona University.

Reinhardt V. 1985. Quantitative analysis of wallowing in a confined bison herd. Acta Theriol. (Warsz). 30:149–156.

Reiter M, Chamberlain RM. 2011. Alternative perspectives of crustal and upper mantle phenomena along the Rio Grande rift. GSA Today 21:4–9.

Rivals F, Solounias N, Mihlbachler M. 2007. Evidence for geographic variation in the diets of late Pleistocene and early Holocene Bison in North America, and differences from the diets of recent Bison. Quat. Res. [Internet] 68:338–346. Available from: http://www.sciencedirect.com/science/article/pii/S0033589407000956

Rosas CA, Engle DM, Shaw JH, Palmer MW. 2008. Seed dispersal by Bison bison in a tallgrass prairie. J. Veg. Sci. [Internet] 19:769–778. Available from: http://dx.doi.org/10.3170/2008-8-18447

Sanderson EW, Redford KH, Weber B, Aune KE, Baldes D, Berger J, Carter D, Curtin C, Derr JN, Dobrott S, et al. 2008. The ecological future of the North American bison: conceiving long-term, large-scale conservation of wildlife. Conserv. Biol. [Internet] 22:252–266. Available from: http://doi.wiley.com/10.1111/j.1523-1739.2008.00899.x

Santucci V, Kenworthy J, Kerbo R. 2001. An Inventory of Paleontological Resources Associated with National Park Service Caves. Available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.161.3797&rep=rep1&type=pdf

Savory A, Butterfield J. 1999. Holistic management: a new framework for decision making. Washington D.C.: Island Press.

Scott E, Cox SM. 2008. Late Pleistocene distribution of Bison (Mammalia; Artiodactyla) in the Mojave desert of southern California and Nevada. Sci. Ser. [Internet] 41:359–382. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:late+Pleistocene+distribution+of+bison+(mammalia;+artiodactyla)+in+the+mojave+desert+of+southern+california+and+nevada#0

SDAIB. 2013. South Dakota Animal Industry Board. Available from: http://www.aib.sd.gov/

Seager R, Graham N, Herweijer C, Gordon AL, Kushnir Y, Cook E. 2007. Blueprints for Medieval hydroclimate. Quat. Sci. Rev. [Internet] 26:2322–2336. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0277379107001242

Shakun JD, Carlson AE. 2010. A global perspective on Last Glacial Maximum to Holocene climate change. Quat. Sci. Rev. [Internet] 29:1801–1816. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0277379110000946

Sharrock FW. 1966. Prehistoric occupation patterns in southwestern Wyoming and cultural relationships with the Great Basin and Plains cultural areas. Univ. Utah Anthropol. Pap. 77.

Skinner MF, Kaisen OC. 1947. 0. C. KAISEN. 1947. The fossil Bison of Alaska and preliminary revision of the genus. Bulleitin Am. Museum Nat. Hist. [Internet] 89. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:The+Fossil+Bison+of+Alaska+and+Preliminary+Revision+of+the+Genus#1

SMA. 2012. Bison Feedlot Production Information.

Smartt RA, Lucas SG, Hafner DJ. 1991. The giant bison (Bison latifrons) from the middle Rio Grande Valley of New Mexico. Southwest. Nat. 36:136–137.

Smith J, Santucci V. 2001. Vertebrate Ichnostratigraphy of the Glen Canyon Group (Jurassic) in Zion National Park, Utah. In: Reynolds RE, editor. The Changing Face of the East Mojave Desert. Vol. 17. Riverside, California: Desert Symposium. p. 15–19. Available from: http://biology.fullerton.edu/Dept/facilities/dsc/pdf/2001changingface.pdf#page=15

Starkovich B. 2011. Faunal Analysis of Walnut Canyon, Arizona. Available from: https://cens.nau.edu/Orgs/CPCESU/current/documents/UAZCP234FinalReport.pdf

Stein W. 1963. Mammal remains from archaeological sites in the Point of Pines region, Arizona. Am. Antiq. [Internet] 29:213–220. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:MAMMAL+REMAINS+FROM+ARCHAEOLOGICAL+SITES+IN+THE+POINT+OF+PINES+REGION+,+ARIZONA#0

Stronen A V., Paquet PC. 2013. Perspectives on the conservation of wild hybrids. Biol. Conserv. [Internet] 167:390–395. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0006320713003133

Teague LS, Deaver WL. 1989. The 1982-1984 Excavations at Las Colinas. Tucson, Arizona Cult. Resour. Manag. Div. Arizona State Museum, Univ. Arizona.

Thompson RS, Mead JI. 1982. Late Quaternary environments and biogeography in the Great Basin. Quat. Res. [Internet] 17:39–55. Available from: http://www.sciencedirect.com/science/article/pii/0033589482900448

USDA. 2009. Census of Agriculture 2007: Summary and State Data. Washington D.C.

USGS, Cole KL. 2008. Prehistoric packrats piled up clues to climate change. United State Geol. Surv. Fact Sheet 3053:1–2.

Van Vuren D, Bray M. 1986. Population dynamics of bison in the Henry Mountains, Utah. J. Mammal. 67:503–511.

Van Vuren D, Dietz FC. 1993. Evidence of Bison bison in the Great Basin. Gt. Basin Nat. 53:318–319.

Wagner FH. 1978. Livestock grazing and the livestock industry. In: Brokaw HP, editor. Wildlife and America: Contributions to an understanding of American wildlife and its conservation. Washington D.C. p. 532.

Wakeling BF. 2006. Arizona bison genetics: verifying origins. In: Cain III JW, Krausman PR, editors. MANAGING WILDLIFE IN THE SOUTHWEST: New Challenges for the 21 st Century. Tucson, Arizona: A Publication of the Southwest Section of The Wildlife Society. p. 25–30. Available from: https://pantherfile.uwm.edu/latch/www/pdfs/Latch et al 2007 - bighorn sheep.pdf

Walker DN. 1983. Faunal remains and subsistence practices at 5MF605, a fur trading post in northwest Colorado. Southwest. Lore 49:6–29.

Wanner H, Solomina O, Grosjean M, Ritz SP, Jetel M. 2011. Structure and origin of Holocene cold events. Quat. Sci. Rev. [Internet] 30:3109–3123. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0277379111002149

Weng CL, Jackson ST. 1999. Late Glacial and Holocene vegetation history and paleoclimate of the Kaibab Plateau , Arizona. Palaeogeogr. Palaeoclimatol. Palaeoecol. 153:179–201.

Whittaker AC. 2012. How do landscapes record tectonics and climate? Lithosphere [Internet] 4:160–164. Available from: http://lithosphere.gsapubs.org/cgi/doi/10.1130/RF.L003.1

Wilson GA, Strobeck C. 1999. Genetic variation within and relatedness among wood and plains bison populations. Genome [Internet] 42:483–96. Available from: http://www.ncbi.nlm.nih.gov/pubmed/10382295

Wilson MC. 1978. Archaeological kill site populations and the Holocene evolution of the genus Bison. Plains Anthropol. 23:9–22.

Withers K, Mead J. 1993. Late Quaternary vegetation and climate in the Escalante River basin on the central Colorado Plateau. West. North Am. Nat. [Internet] 53:145–161. Available from: https://journals.lib.byu.edu/spc/index.php/wnan/article/view/28567

Wolverton S, Randklev C, Barker A. 2011. Ethnobiology as a bridge between science and ethics: an applied paleozoological perspective. Ethnobiology [Internet]:115–132. Available from: http://www.researchgate.net/publication/230293389_Ethnobiology_as_a_Bridge_between_Science_and_Ethics_An_Applied_Paleozoological_Perspective/file/e0b4952268930a36b8.pdf

Woodson K. 2007. The Goat Hill Site and Ancestral Pueblo Migrations into the Safford Basin. Petroglyph, Newsl. Arizona Archaeol. Soc. 43:7–11.

Wright R. 1998. A review of the relationships between visitors and ungulates in national parks. Wildl. Soc. Bull. [Internet] 26:471–476. Available from: http://www.jstor.org/stable/3783759

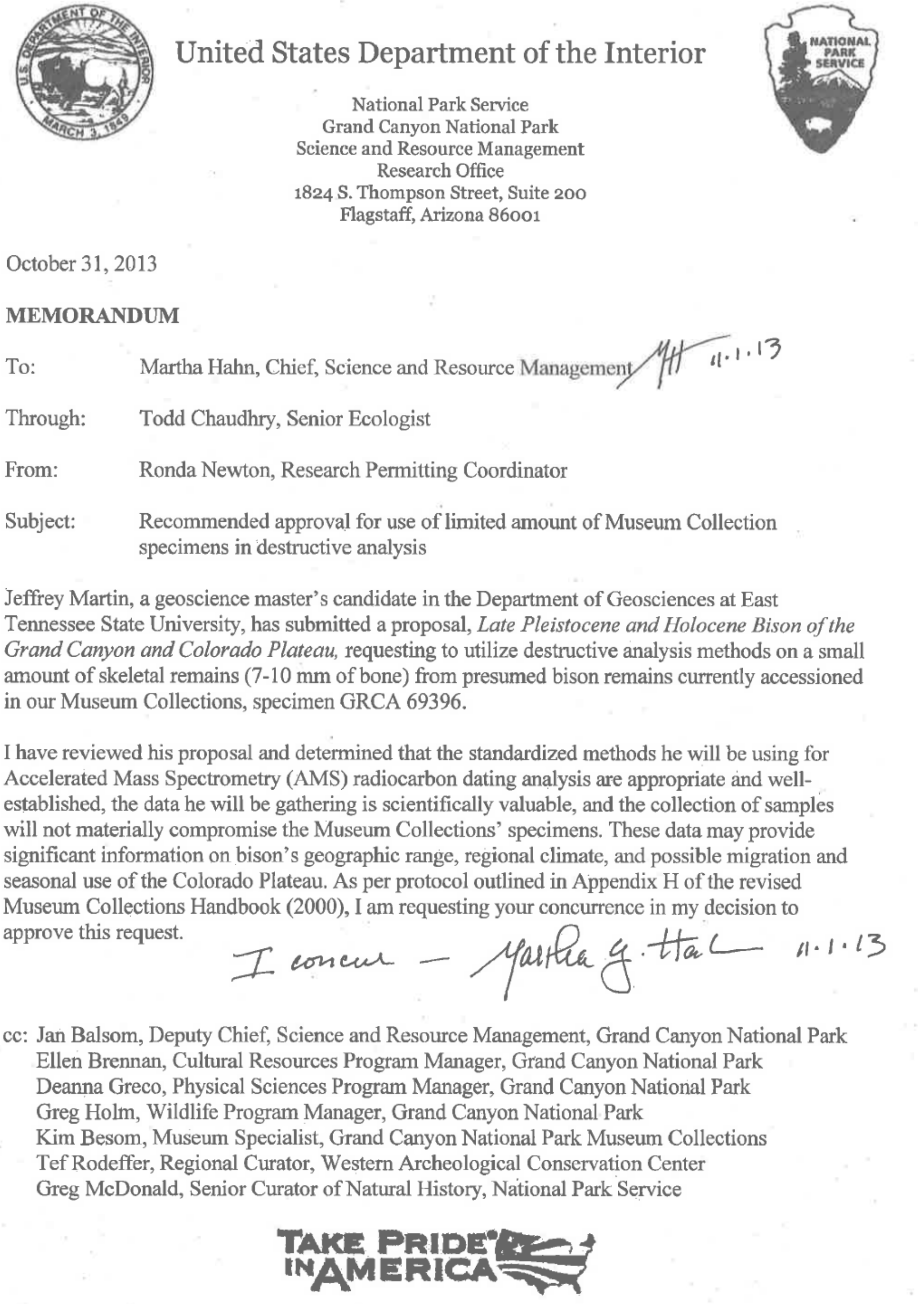
Zalasiewicz J, Williams M, Haywood A, Ellis M. 2011. The Anthropocene: a new epoch of geological time? Philos. Trans. R. Soc. A [Internet] 369:835–841. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21282149

Zhao M, Huang C-Y, Wei K-Y. 2005. A 28,000 Year U K37 Sea-Surface Temperature Record of ODP Site 1202B, the Southern Okinawa Trough. TAO 16:45–56.

Zhu K, Woodall CW, Ghosh S, Gelfand AE, Clark JS. 2014. Dual impacts of climate change: forest migration and turnover through life history. Glob. Chang. Biol. 20:251–264.

APPENDICES

Appendix A: Research Permit for Grand Canyon National Park



United States Department of the Interior

National Park Service
Grand Canyon National Park
Science and Resource Management
Research Office
1824 S. Thompson Street, Suite 200
Flagstaff, Arizona 86001

October 31, 2013

MEMORANDUM

To: Martha Hahn, Chief, Science and Resource Management MH 11.1.13

Through: Todd Chaudhry, Senior Ecologist

From: Ronda Newton, Research Permitting Coordinator

Subject: Recommended approval for use of limited amount of Museum Collection specimens in destructive analysis

Jeffrey Martin, a geoscience master's candidate in the Department of Geosciences at East Tennessee State University, has submitted a proposal, *Late Pleistocene and Holocene Bison of the Grand Canyon and Colorado Plateau,* requesting to utilize destructive analysis methods on a small amount of skeletal remains (7-10 mm of bone) from presumed bison remains currently accessioned in our Museum Collections, specimen GRCA 69396.

I have reviewed his proposal and determined that the standardized methods he will be using for Accelerated Mass Spectrometry (AMS) radiocarbon dating analysis are appropriate and well-established, the data he will be gathering is scientifically valuable, and the collection of samples will not materially compromise the Museum Collections' specimens. These data may provide significant information on bison's geographic range, regional climate, and possible migration and seasonal use of the Colorado Plateau. As per protocol outlined in Appendix H of the revised Museum Collections Handbook (2000), I am requesting your concurrence in my decision to approve this request.

I concur — Martha G. Hahn 11.1.13

cc: Jan Balsom, Deputy Chief, Science and Resource Management, Grand Canyon National Park
Ellen Brennan, Cultural Resources Program Manager, Grand Canyon National Park
Deanna Greco, Physical Sciences Program Manager, Grand Canyon National Park
Greg Holm, Wildlife Program Manager, Grand Canyon National Park
Kim Besom, Museum Specialist, Grand Canyon National Park Museum Collections
Tef Rodeffer, Regional Curator, Western Archeological Conservation Center
Greg McDonald, Senior Curator of Natural History, National Park Service

TAKE PRIDE IN AMERICA

SCIENTIFIC RESEARCH AND COLLECTING PERMIT

Grants permission in accordance with the attached
general and special conditions
United States Department of the Interior
National Park Service
Grand Canyon

Study#: GRCA-00637
Permit#: GRCA-2013-SCI-0052
Start Date: Dec 01, 2013
Expiration Date: Mar 01, 2014
Coop Agreement#:
Optional Park Code:

Name of principal investigator:
Name: Mr Jeffrey Martin **Phone:**7158211812 **Email:**martinjm1@goldmail.etsu.edu

Name of institution represented:
East Tennessee State University

Co-Investigators:
Name: Dr. Jim I. Mead **Phone:** 423-439-7515 **Email:** mead@etsu.edu

Study Title:
Holocene and late-Pleistocene Bison of the Grand Canyon and the Colorado Plateau

Purpose of study:
Bison have long been regarded as non-existent, both historically and prehistorically, in the Southwest, particularly on the Colorado Plateau. Bison are not thought to have had a presence before 1906 based on historical documents, including expedition journals and published peer-reviewed papers. However, these documents do not address why the cataloged 'cattle/cow' remains are morphologically distinct as 'Bos taurus' and not 'Bison bison'. Other museum visits conducted by the author in the region of the Grand Canyon confirm that many of the collections specimens cataloged are misidentified as 'Bos taurus' and are actually 'Bison bison'. Today, knowing the history and prehistory of bison's native range is important because a herd of 300-400 Bison is living on the North Rim (Kaibab Plateau) of the Grand Canyon. Currently, conservationists and policy considers Bison (based on inconclusive research) to be a human-introduced, invasive species to the Grand Canyon region; yet, Bison fossil and sub-fossil records suggest that they are, in fact, native to the area, but more research must be completed. The necessary research involves examining cataloged specimens and radiocarbon-dating those specimens to determine exactly when the Bison inhabited the area.

Subject/Discipline:
Animal Communities / Wildlife
Exotic / Invasive Animals
Land Use / Rangeland
Mammals

Locations authorized:
GRCA Museum Collection located on the south rim of Grand Canyon National Park

Transportation method to research site(s):
Vehicle travel on open, existing roads

Collection of the following specimens or materials, quantities, and any limitations on collecting:
One 7-10 mm sample of bison/bos bone is authorized for collection by GRCA Wildlife Biologist, Brandon Holton. PI will coordinate time and date of sample collection prior to arrival in park, Brandon_Holton@nps.gov, 928-638-7752. Destructive analysis techniques are permitted.

Name of repository for specimens or sample materials if applicable:

Specific conditions or restrictions (also see attached conditions):
CONDITIONS SUBJECT TO ALL GRCA PERMITS-NON-RIVER USE
1. UTM Zone 12N NAD83 is to be used by all researchers to ensure compatibility with all GRCA GIS layers.
2. Reporting Requirements
a. Reports and datasets: Copies of all maps, data, reports, etc. will be archived at Grand Canyon upon completion of study.
b. Submit a Final Report within six months of completion of study or expiration date of this permit. This report can be submitted electronically to grca_research_coordinator@nps.gov, or via hard copy to: Grand Canyon NP Research Coordinator, 1824 S. Thompson St., Ste. 200, Flagstaff, AZ 86001.
c. All final reports and documentation resulting from this study are to be submitted to the park for review before distributing to the public/press.
d. PI is required to submit datasets and reports from any previous permitted research before a new or renewal of a permit will be considered. The 90-day evaluation period will not start until datasets and reports are received by the GRCA Research Permit

Coordinator.

3. Breach of any of the terms of this permit or for violation of park regulations will be grounds for revocation of this permit and denial of future permits. Citations may be issued for adverse actions and violations of this permit.

4. PI will meet with the GRCA staff as needed to discuss the conditions of their permit.

5. GRCA staff is authorized to accompany research trips and provisions will be made for park participants.

6. In accordance with the Paleontological Resources Protection Act of 2009 (PL 111-11), resources collected from federal land are federal property. All collected resources and copies of associated records will be preserved and made available for the public and researchers (Sec. 6304. C. 1-2). In addition, any resources and data and records collected will be stored and curated in an approved repository (Sec. 6305). For additional information on PL 111-11, contact GRCA Physical Sciences Program Manager, Deanna Greco, at (928) 638-7817.

7. By signing this document, I hereby affirm that I will abide by the DOI policy set forth in the DOI Departmental Manual, DOI Departmental Management Series, Part 305, Ch. 3, Sec. 3.7, and with Director's Order #79 (Integrity of Scientific and Scholarly Activities).

8. If you collect specimens that are to be permanently retained, regardless of where they are kept, they must be accessioned and cataloged into the NPS catalog system, and must bear NPS accession and catalog numbers. For assistance, contact the Curator's Office at (928) 638-7769, or GRCA_Museum_Collection@nps.gov. Copies of all catalogue records will be submitted to GRCA Museum Collection upon completion of cataloging.

9. I agree to keep confidential any protected information that I may develop or otherwise acquire as part of my work with the NPS. I understand that with regard to protected information, I am an agent of the NPS and must not release that information. I also understand that by law I may not share protected information with anyone through any means except as specifically authorized by the NPS. I understand that protected information concerns the nature and specific location of endangered, threatened, rare, commercially valuable, mineral, paleontological, or cultural patrimony resources such as threatened or endangered species, rare features, archeological sites, museum collections, caves, fossil sites, gemstones, and sacred ceremonial sites. Lastly, I understand that protected information must not be inadvertently disclosed through any means including websites, maps, scientific articles, presentation and speeches.

10. Unless otherwise authorized on your permit, you must carry out all of your activities out of public view. If you have obtained special permission to work in public view, it will be noted on your permit-specific conditions. Please consult these conditions for further guidance. If sampling at some sites cannot be accomplished out of public view, please contact the Research Office at (928) 638-7447 to obtain a uniformed escort.

11. PI is responsible for the research-related activities of your staff. Please ensure that field staff adhere to all conditions of your permit. Field staff must possess a copy of your permit at all times while in the field.

12. This research permit does not authorize entrance into closed or restricted areas of the park. The following are restricted areas and entrance is prohibited: Anasazi Bridge; Furnace Flats archaeological site; caves and mine shafts or adits including but not limited to Bass Mine, Hance Mine, Hopi Salt Mine, Orphan Mine, Deer Creek Narrows, and Maricopa Point. If you have obtained special permission to work in one of these areas, it will be noted on your permit-specific conditions.

13. PI agrees to notify the superintendent of GRCA of every subject discovery or invention that relates in any respect to research results derived from use of any research specimens or other materials collected from GRCA, or that may be patentable or otherwise protected under the intellectual property (IP) laws of the United States or other jurisdiction. Notification must occur within sixty days of the time that an inventor or other agent of the PI reports such a subject discovery or invention to the persons responsible for patent or other proprietary rights matters in the PI's organization, and in no case not less than sixty days before a patent application is filed. Additionally, the PI agrees to notify the superintendent of GRCA within thirty days of filing any patent application or other IP claim in the United States or other country that relates in any respect to research results or other discoveries or inventions derived from use of any research specimens or other materials collected from GRCA. For purposes of this paragraph, the term "subject discovery or invention" means any discovery or invention related to or derived from research specimens or other materials collected from GRCA. All invention disclosures shall be marked as confidential under 35 U.S.C. Section 205.

14. This permit does not authorize the bearer or those that accompany them to conduct commercial filming activities. Commercial film permits must be obtained from the Concessions Management office (928-638-7707).

15. Each year, PIs are required to submit copies of journal articles, theses, and dissertations that resulted from park research activities to the Research Office. Documents should be submitted in .pdf format, with the exception of theses/dissertations, which should be sent as bound documents.

16. By signing this permit, I acknowledge that I have read, understand, and will abide by the General Conditions subject to all National Park Service research permits. These conditions are found at the following website:
https://science.nature.nps.gov/research/ac/ResearchIndex

THIS PERMIT SERVES AS YOUR GATE PASS THROUGH 3/1/2014.

A copy of this permit should be displayed visibly in your parked vehicle when in the park.

Recommended by park staff(name and title):

Reviewed by Collections Manager:

Yes ____ No ____

Approved by park official:

Date Approved:

Title:

Chief, Science & Resource Management

I Agree To All Conditions And Restrictions Of this Permit As Specified
(Not valid unless signed and dated by the principal investigator)

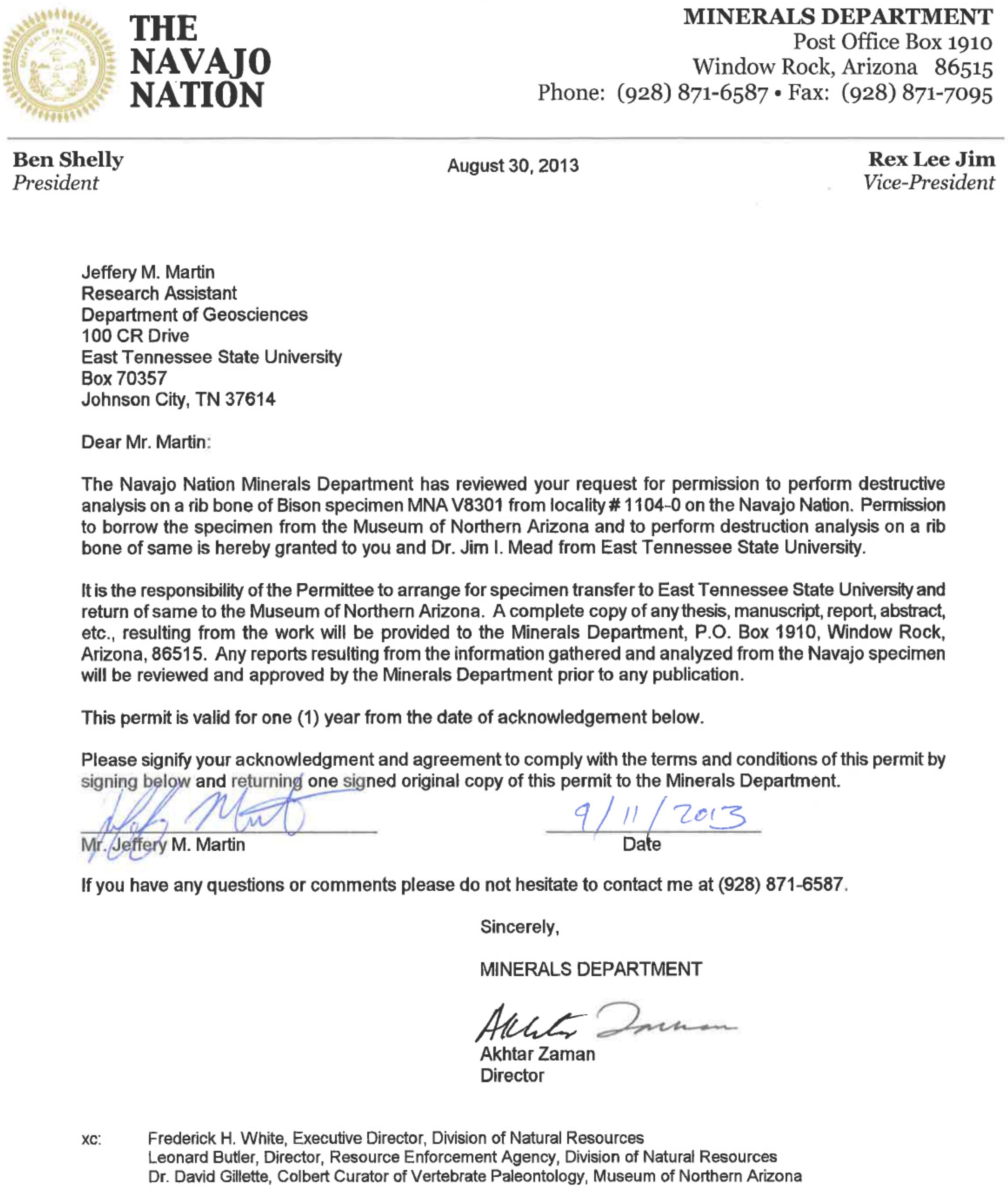
11/05/2013

(Principal investigator's signature) JIM MEAD (Date)

Jeff Martin

THIS PERMIT AND ATTACHED CONDITIONS AND RESTRICTIONS MUST BE CARRIED AT ALL TIMES WHILE CONDUCTING RESEARCH ACTIVITIES IN THE DESIGNATED PARK(S)

Appendix B: Research Permit for Navajo Nation and Museum of Northern Arizona



THE NAVAJO NATION

MINERALS DEPARTMENT
Post Office Box 1910
Window Rock, Arizona 86515
Phone: (928) 871-6587 • Fax: (928) 871-7095

Ben Shelly
President

Rex Lee Jim
Vice-President

August 30, 2013

Jeffery M. Martin
Research Assistant
Department of Geosciences
100 CR Drive
East Tennessee State University
Box 70357
Johnson City, TN 37614

Dear Mr. Martin:

The Navajo Nation Minerals Department has reviewed your request for permission to perform destructive analysis on a rib bone of Bison specimen MNA V8301 from locality # 1104-0 on the Navajo Nation. Permission to borrow the specimen from the Museum of Northern Arizona and to perform destruction analysis on a rib bone of same is hereby granted to you and Dr. Jim I. Mead from East Tennessee State University.

It is the responsibility of the Permittee to arrange for specimen transfer to East Tennessee State University and return of same to the Museum of Northern Arizona. A complete copy of any thesis, manuscript, report, abstract, etc., resulting from the work will be provided to the Minerals Department, P.O. Box 1910, Window Rock, Arizona, 86515. Any reports resulting from the information gathered and analyzed from the Navajo specimen will be reviewed and approved by the Minerals Department prior to any publication.

This permit is valid for one (1) year from the date of acknowledgement below.

Please signify your acknowledgment and agreement to comply with the terms and conditions of this permit by signing below and returning one signed original copy of this permit to the Minerals Department.

Mr. Jeffery M. Martin

9/11/2013
Date

If you have any questions or comments please do not hesitate to contact me at (928) 871-6587.

Sincerely,

MINERALS DEPARTMENT

Akhtar Zaman
Director

xc: Frederick H. White, Executive Director, Division of Natural Resources
Leonard Butler, Director, Resource Enforcement Agency, Division of Natural Resources
Dr. David Gillette, Colbert Curator of Vertebrate Paleontology, Museum of Northern Arizona

VITA

JEFF M. MARTIN

Education:	Public Schools, Ellsworth, Wisconsin B.S. Geology, East Tennessee State University, Johnson City, Tennessee 2012 M.S. Geosciences, East Tennessee State University, Johnson City, Tennessee, 2014
Professional Experience:	ETSU Department of Geosciences Research Assistant, August 2012 – May 2014 Crew Chief of Excavations, Pleistocene Site in Saltville, Virginia, May – June 2013 Paleontological Technician Intern – Cohort II, National Science Foundation and University of Florida's Panama Canal Project – Partnerships for International Research and Education,May – August 2012
Publications:	J. M. Martin and J. I. Mead. (2014). "Reevaluation of Bison remains from the greater Grand Canyon region and Colorado Plateau: native or non-native?" in 10th North American Paleontological Convention: Abstract Book: Paleontological Society Special Publications Volume 13:59. J. M. Martin, H. A. Zamora, H. B. Riegel, J. R. Carr, and A. R. Wood. (2012). "New Freshwater Molluscs from the Panama Canal Miocene Cucaracha Formation and Paleoenvironmental Reconstruction Implications." in 2012 Annual Meeting & Exposition: GEOSCIENCES: Investing in the Future Abstract Book. H. B. Riegel, A. R. Wood, H. A. Zamora, J. M. Martin, J. R. Carr. (2012). "Paleoenvironments of the Upper Cucaracha Formation (Early Miocene, Panama): Evidence from Pedofacies and Fluvial Deposits." in 2012 Annual Meeting & Exposition: GEOSCIENCES: Investing in the Future Abstract Book.
Honors and Awards:	2014-2016. U.S. National Science Foundation's Integrative Graduate Education and Research Traineeship (IGERT) trainee in Adaptation to Abrupt Climate Change for the University of Maine, Orono. 2013. East Tennessee State University Graduate School's Graduate Research Grant awardee for this thesis. 2013. National Buffalo Foundation Research Grant awardee for this thesis. 2013. Experiment.com (previously Microryza.com) Crowdsource Funded Research Funds for this thesis. 2012 & 2013. East Tennessee State University and Don Sundquist Center of Excellence in Paleontology Research Grant awardee for this thesis.