

ABSTRACT

Title of Thesis:

REACHING FOR THE STARS: A MULTI-METHODS APPROACH TO UNDERSTANDING NAVAJO STAR CEILINGS

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Star ceilings are a type of Native American pictographic rock art style characterized by cruciform icons that symbolically represent the stars of the night sky, and they are generally found throughout the Four Corners region of the Southwestern United States. According to the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) *Portal to the Heritage of Astronomy*, there are approximately 80 known star ceiling sites (2025). Star ceilings are attributed to the Navajo people—also known as the *Diné*—because they are primarily found on traditional Navajo/*Diné* lands (Chamberlain and Schaafsma 2005; UNESCO 2025). These pictographic artworks are typically found in cave sites, spring sites, and underneath cliff and/or rock overhangs, and they are known to contain deep spiritual significance and power for the Navajo people (Chamberlain and Schaafsma 2005).

Because this work is a multi-methods approach—that is, I use several techniques to collect data and use data—I base my research activity on several data-collection techniques that coalesce around one thesis research question: How can combining traditional rock art research techniques, such as fieldnotes and photography, together with modern technologies, like portable

X-ray fluorescence (pXRF) pigment analysis, Artificial Intelligence (AI), and Virtual Reality (VR), provide new insights into the material choices, ritual painting processes, and digital research and preservation of Navajo star ceilings, and what does this reveal about the potential usefulness of emerging digital tools for documenting, conserving, and preserving ancient rock art?

This thesis aims to expand existing star ceiling research through data collection performed at two distinct sites—one found on private land and the other on Bureau of Land Management (BLM) public land—both located within the traditional Navajo landscape (*Diné'tah*). This research utilizes modern analytical techniques, specifically pXRF, to identify the elemental chemical constituents of star ceiling pictographs. By uncovering the material makeup of the pigments used at two star ceiling sites, this thesis offers a deeper understanding of their original production and use. Furthermore, this project experiments with emerging technologies like AI and VR to assess their effectiveness and suitability as tools for digital reconstruction and restoration. By testing these innovative approaches, this thesis also evaluates whether AI and VR are viable and practicable vehicles for documenting and analyzing rock art in general—and sacred star ceiling sites in particular—ultimately supporting the long-term interpretation and preservation of these fragile artworks.

Star ceilings are now found on UNESCO's Astronomical Heritage list, and it is vital that we work to understand them and to find pathways to think about protecting and preserving them. While specific to the Navajo cultural experience, these simple and beautiful artworks capture a human yearning shared by all people and cultures, I believe: the desire for a real connection to the night sky and to the stars and the power that the stars symbolically represent.

REACHING FOR THE STARS: A MULTI-METHODS APPROACH
TO UNDERSTANDING NAVAJO STAR CEILINGS

by

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Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Master of Professional Studies in Cultural
and Heritage Resource Management
2026

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Foreword

A Personal Note

Since this is a Master of Professional Studies program and curriculum, I have endeavored to engage with innovative systems of data collection and interpretation, as well as new technologies, as a way to not only expand academic knowledge in general but to also expand my own personal and professional horizons. All of the techniques used in this thesis interest me and I think they prove useful in the archaeological and rock art studies milieu. My sincere wish is that this thesis will prove useful to others too.

I have had the opportunity to study Navajo star ceilings for many years. These beautiful artworks are in many respects a profound mystery. We can only hint at their function and their meanings. Since my first efforts to understand these artworks, beginning in 2010, Navajo star ceilings have become included on the United Nations Educational, Scientific, and Cultural Organization's World Heritage List under the Category of Astronomical Heritage. To me, this fact makes the study of Navajo star ceilings not only important to archaeological research but to world heritage as well.

Even though they are central to Navajo cosmological understandings of the night sky, these artworks somehow touch upon an important aspect of what it means to be human. They serve as a symbolic representation of the human yearning for practical and spiritual connection to the night sky, to something powerful beyond the limits of time and space. Since in Navajo understanding the representation of a thing is the thing itself, for the Navajo these stellar artworks make the stars' power accessible to the people on the earth, they are "meant to have the

power of the stars themselves” (Chamberlain and Schaafsma 2005:92). For this reason, among others, these artworks and the sites they are found within ought to be considered with respect.

It has been a great honor and privilege for me to research Navajo star ceilings. I did not casually perform this thesis work; rather, I attempted to maintain a spirit of humility throughout the entire process. Though I may not comprehend Navajo star ceilings fully, and will most likely never be able to, I understand Navajo star ceilings to be incredibly sacred. Therefore, I attempt to ask the research questions with reverence, and to interpret with care.

Dedication

This work is dedicated to Teresa and to the Navajo Stars.

Acknowledgments

First and foremost, I'd like to thank Dr. Matthew Palus for his time and kind guidance throughout this project. Without his patience and expertise this thesis would not have taken shape. I am equally grateful to my Thesis Committee members for their time and engagement with this work.

I also want to honor Dr. Paul Zolbrod and Dave Brugge. Though they are no longer with us, their intellectual guidance remains in their academic works and in my heart. They were scholars who cared for the Navajo people in real and enduring ways, and their influence continues to shape my view of Navajo art and culture. They set a high bar for academic research and genuine humility.

Polly Schaafsma's scholarship has long inspired me, and her work remains an intellectual foundation for me.

Dr. Carolyn Boyd's work forms a huge piece of my approach to studying star ceilings in this thesis. I am grateful to her for providing a conceptual framework for studying ancient rock art.

The Navajo people are the *sine qua non* of this thesis. I am profoundly grateful for their culture, their history, and the simple beauty of the artworks that form the foundation of this study. There is no adequate way to express my thanks.

I am grateful to Kathy Davis and Dr. Daron Duke at Far Western for supporting the pXRF analysis at the two star ceiling sites, as well as to Ioana Cortea at INFRA-ART for her time and insight into the interpretation of the pXRF data. Professor Victoria Clow offered conservation guidance regarding star ceilings and rock art, and I thank her for her time. I am also

indebted to Dr. Linda Scott Cummings and V.A. Varney at PaleoResearch Institute for their work on the mano analysis.

My sincere thanks goes to Jay Salois at VRtical Media, whose time training me in 3D photogrammetry and VR techniques expanded the impact of this project. I am indebted to him for his expertise.

I also thank Sean Dougherty and Michael Merritt at the BLM for their support in granting me access to the BLM site that forms a foundation for this thesis. I am equally grateful to the owners of the private star ceiling site, whose generosity allowed this study to move forward.

My family has always encouraged me to pursue meaning and the things that interest me. Their support continues to move me forward, especially Teresa's.

Amy Winters has provided editorial guidance that has helped shape this work. I am eternally grateful to her for her work in helping me structure and refine this thesis.

Lastly, and importantly, I acknowledge the traditional landscapes of the Four Corners region and the cultures that inhabit this land. This land is alive with meaning and deep cultural history, and I have been fortunate to conduct research within it. For that opportunity, I remain deeply thankful. It has changed my life in profound ways.

Table of Contents

Foreword	ii
A Personal Note	ii
Dedication	iv
Acknowledgments	v
Table of Contents	vii
List of Tables	ix
List of Figures	x
Chapter 1: Introduction	1
A Definitional Note	5
Chapter 2: Theoretical Background	6
Theoretical Considerations	6
XRF and Rock Art	8
AI and Rock Art	9
VR and Rock Art	10
Some Final Thoughts on Theoretical Orientation	11
Chapter 3: Historical and Cultural Background with Environmental Setting	17
Historical Background	17
Star Ceilings in Navajo Culture and Myth: A Brief Literature Review	19
Known Locations and Dating and Other Reflections	24
Mud Balls	27
The Environmental Setting: A Description of the Sites	28
Site 1	29
Site 2	32
Geography, Elevation, and Biota for Both Sites	34
Chapter 4: Methods	37
A Word to Begin	37
Methods of Research	37
Research Permissions at Site 1 and Site 2	38
Background Research	39
Fieldnotes and Sketches	40
Field Photography	41
Pollen Analysis of a Mano from Site 1	41
Artificial Intelligence	43
Virtual Reality	45
Consultation with Conservators	47
Chapter 5: Results	49
Field Data and pXRF Results	49
Fieldnotes and Sketches Results	49
Field Photography Results	53
The Results of Other Archaeological Features and Artifacts, as Witnessed in the Fieldwork	55

Pollen Analysis Results of a Mano from Site 1	58
Portable X-Ray Fluorescence Results.....	61
Emerging Technologies: Artificial Intelligence and Virtual Reality	77
Results of Experimentation with Artificial Intelligence	77
Results of Experimentation with Virtual Reality.....	91
Consultation with Conservator	99
Summarizing Remarks.....	100
Chapter 6: Analysis.....	101
Foundational Thoughts on Analysis for This Thesis	101
Analysis of Recordation, Fieldnotes, Sketches, and Photography.....	102
Analysis of Other Archaeological Features and Artifacts	112
Analysis of Pollen from a Mano at Site 1	115
Analysis of pXRF	116
Analysis Using Emerging Technologies: Artificial Intelligence and Virtual Reality	119
Analysis with Artificial Intelligence.....	119
Analysis with Virtual Reality Renderings	124
Consultation with a Conservator.....	131
Summary	132
Chapter 7: Conclusion.....	133
Limitations	138
Suggestions for Further Research	141
Appendix 1: Archaeological Site Summary for Site 2.....	145
Appendix 2: ARPA Permit for Site 2	150
Appendix 3: Archaeological Field Notes of Sites 1 and 2.....	154
Appendix 4: Mano Analysis for Site 1	164
Appendix 5: Far Western XRF Navajo Pictograph Report	169
Appendix 6: INFRA-ART's Results of the XRF Analysis.....	188
Appendix 7: Reprint Permissions	204
Bibliography	216

List of Tables

Table 1: Star Size and Handprint and Amorphous Pictograph Measurements Based on Sketch Measurements	51
Table 2: Pollen Types Found on Mano (Cummings 2025:4)	60
Table 3: Elements Identified in Analyzed Pigments, as Reported by Far Western	63

List of Figures

Figure 1: Red Star pictograph from Ojo Jarido Star Ceiling (Site 2).	7
Figure 2: Plate XIV Sandpainting by Jeff King.	22
Figure 3: Generalized map of star ceiling sites in New Mexico.	25
Figure 4: Wide view of mud ball offerings from a star ceiling site (Site 2).	27
Figure 5: More mud ball offerings adjacent to a star pictograph at a star ceiling site (Site 2).	28
Figure 6: Site 1, Alcove 1. Alcove 1 contains one star.	31
Figure 7: Site 1, Alcove 2. Alcove 2 contains five stars.	31
Figure 8: Site 2, cave mouth.	33
Figure 9: Site 1, Alcove 2, Stars 1-5, in a potential constellatory pattern.	52
Figure 10: Rough sketch of locations of stars and mudballs at Site 2.	53
Figure 11: Site 2, Star 1 may have been painted with the artist's finger.	55
Figure 12: Site 1, Alcove 1, Petroglyphs of "broad-shouldered men"	56
Figure 13: Site 1, Alcove 2, Bentonite clay vein.	57
Figure 14: Example of petroglyphs adjacent to Site 2.	58
Figure 15: Manos found inside Site 1, Alcove 1.	61
Figure 16: Site 1, Star 1, found in Alcove 2	65
Figure 17: Site 1, Star 2, found in Alcove 2	66
Figure 18: Site 1, Star 3, found in Alcove 2	66
Figure 19: Site 1, Star 4, found in Alcove 2	67
Figure 20: Site 1, Star 5.	68
Figure 21: Site 1, Star 6, found in Alcove 1.	69
Figure 22: Site 1, Star 6, found in Alcove 1.	70
Figure 23: Site 2, Star 1.	71
Figure 24: Site 2, Star 2.	71
Figure 25: Site 2, amorphous black.	72
Figure 26: Site 2, handprints.	72
Figure 27: Site 2, mudball examples.	73
Figure 28: Adjacent to Site 2, Sun and Moon.	74
Figure 29: Adjacent to Site 2, Sun and Moon.	75
Figure 30: Adjacent to Site 2, Bear.	76
Figure 31: Adjacent to Site 2, Chicken.	76
Figure 32: Photo of pictographs from Site 2 without AI reconstruction.	78
Figure 33: Digital image of the AI-reconstructed pictographs	79
Figure 34: Photo of pictograph from Site 2 without AI reconstruction.	80
Figure 35: Digital image of the AI-reconstructed Site 2 pictograph	81
Figure 36: Photo of pictograph from Site 2 without digital manipulation.	82
Figure 37: Digital image of pictograph from Site 2 with background digitally removed	83
Figure 38: Pictograph from Site 2 without digital manipulation.	84
Figure 39: Digital image of pictograph from Site 2 with background digitally removed.	85
Figure 40: Photo of pictograph from Site 2 without digital restoration.	86
Figure 41: AI-generated image of areas needing in-filling via Kashkin's method.	87
Figure 42: Digital image of AI-produced digital restoration via Kashkin's method.	88
Figure 43: Photograph of bird-like pictograph found in Site 2 in 2011.	92

Figure 44: Screenshot of VR image of the same bird-like pictograph found in Site 2.....	93
Figure 45: Example of a VR hotspot as seen in this screenshot of the VR rendition of Site 2	94
Figure 46: Another example of a VR hotspot as seen in this screenshot of the VR rendition of Site 2.	95
Figure 47: Drone photograph of the interior of Site 2 taken from above Site 2’s entrance.....	96
Figure 48: Drone photograph of the interior of a small alcove located above Site 2’s entrance..	97
Figure 49: Screenshot of a VR perspective from the entrance of Site 2.....	97
Figure 50: Screenshot of a VR perspective from the entrance of Site 2.....	98
Figure 51: Closeup photo taken by drone during the VR recording of Site 2	98
Figure 52: Navajo rug made by Bobbijo Whitehair entitled “Sunrise Pictorial.”	105
Figure 53: Potential constellation pattern	107
Figure 54: Photograph of Orion’s belt during the winter months from Western North America.	108
Figure 55: Bentonite clay/ <i>Gleesh</i> vein as seen in the interior of Site 1, Alcove 2.	109
Figure 56: Frequencies of pigment colors from Site 2 as obtained from photographic analysis of Site 2	111
Figure 57: Photograph of corn cob and other material found at Site 2 in 2011.....	128
Figure 58: 3D photograph of the same location at Site 2 taken in 2026.....	128
Figure 59: Star Map, The Skidi Pawnee buckskin Chart of the Heavens.....	144

Chapter 1: Introduction

This project is representative of a multi-methods research design that supports greater understanding of Navajo star ceilings, a particular form of ancient Navajo rock art found throughout the Four Corners region of the American Southwest. Star ceilings are known to be sacred artworks for the Navajo people, and they are thought to symbolically represent the stars of the night sky as well as to convey the supernatural power of the stars (Chamberlain and Schaafsma 2005). My main thesis question throughout this research project is: How can combining traditional rock art research techniques, such as fieldnotes and photography, together with modern technologies, like pXRF pigment analysis, AI, and VR, provide new insights into the material choices, ritual painting processes, and digital research and preservation of Navajo star ceilings, and what does this reveal about the potential usefulness of emerging digital tools for documenting, conserving, and preserving ancient rock art?

Star ceilings were first described in the western archaeological literature by the archaeologist David De Harport in 1951 in his survey of Canyon De Chelly and Canyon Del Muerto (De Harport 1951). Since that time, there have been several attempts to describe star ceilings, how they were produced, their significance, and their meaning (Britt 1975; Chamberlain and Schaafsma 2005; Jett 1984). For the better part of 75 years, since De Harport's seminal description, Navajo star ceilings have been analyzed using traditional archaeological and anthropological techniques. But certain modern technologies have not yet been employed with them.

This thesis, therefore, aims to add to the scholarly literature pertaining to Navajo star ceilings by utilizing novel modern analytical instruments and techniques to buttress the

foundational work already done. That is to say, this thesis aims to add to the scholarly literature on Navajo star ceilings by employing new and innovative methods to approach them.

Broadly speaking, this project theoretically uses Carolyn Boyd's multi-methods approach to studying the Pecos River Style rock art found in southwest Texas. Boyd has led several important research projects, and her technique is to gather as much data as possible, from as many angles as possible, via an interdisciplinary methodology, in the effort to synthesize information to create new and meaningful interpretations of the ancient Pecos River Style rock art (Boyd and Cox 2016; Boyd et al. 2023; Shumla Archaeological Research & Education Center 2026). For example, Boyd blends archaeological science, formal art analysis, ethnological material, and indigenous knowledge of rock art to weave together a tapestry of meanings surrounding the enigmatic Pecos River Style artworks (Boyd et al. 2023). The work that Boyd has accomplished with this style of ancient artwork is rich, robust, and incredible.

As such—though not exactly replicating Boyd's approach, but in the spirit of Boyd's approach—the research design employed for this thesis approaches Navajo star ceilings in a similar way to Boyd, with a broad-ranging research question that allows for multiple data-collection techniques and several avenues for interpretation.

By guiding data-collection and interpretation activities along these lines, I hope that this thesis can enable synthesization of data to allow for greater knowledge and understanding of Navajo star ceilings. Though the research design focuses exclusively on two star ceiling sites, one found on privately owned land and the other on Bureau of Land Management (BLM) land, the information collected at these sites does point toward a deeper understanding of these artworks.

Because I am limited in my expertise in certain aspects of the particular techniques used in this thesis, I contracted with several experts to assist in the data-collection and interpretation efforts. Part of my mission with respect to this endeavor included gaining mastery in the techniques employed in this thesis. In this way, this thesis becomes a springboard for not only using novel techniques in researching sacred rock art but also gaining experience in applying emerging technologies in the study of rock art.

Since Navajo star ceilings are now recognized by the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) as being part-and-parcel of the Astronomical Heritage of the World (UNESCO 2025), it is vital that we work to gain more understanding of these beautiful artworks. Therefore, I hope the information obtained in this thesis supports both the expansion of academic knowledge and the efforts toward preserving and conserving this unique form of rock art heritage. What's more, some aspects of this thesis are meant to add to the Navajo THPO's resources pertaining to star ceilings.

A word about sovereignty and ethics: Notwithstanding UNESCO's designation, and my desire to learn more about Navajo star ceilings, there are serious ethical considerations to take into account, and though my general approach is grounded in an ethical commitment to respect the Navajo community and their artworks throughout this research study, I am not a Navajo tribal member and am therefore in the ethically sensitive position of studying Navajo sacred artworks via archaeological techniques while also recognizing that Navajo sovereignty is the final authority on interpretation of the findings of this work (Billie 2021:65,99; Navajo Nation Historic Preservation Department 2008:1).

Therefore, in the spirit of Colwell-Chanthaphonh and Ferguson (2004), I intentionally perform this research from a stance of cultural and interpretive humility. As a result, I attempt to

not over-interpret findings; I sincerely try to protect sensitive information, especially site locational data; I non-invasively and non-destructively approach the study of the artworks themselves; and I acknowledge that ultimately the cultural meanings are not mine to articulate. Thus, my word is not the final word in this thesis; there are limitations in what I can understand and real limits to my authority in interpreting the findings. And importantly, it must be highlighted, too, that though I did attempt to bring living Navajo voices into this thesis, not merely as community stakeholders for my project, but as real partners with real voices, I was not successful in receiving feedback either on my methods or my results. This fact has added a challenging dilemma for me personally, as it created an internal conflict based on whether or not I should study these artworks at all. This question is an important one, and it led me to commit myself even more to an ethically grounded set of responsible research actions.

Organization of This Thesis

This thesis is structured in the following way:

Chapter 2 provides the theoretical background for this thesis, detailing the theoretical approaches employed in this project to approach the study of Navajo star ceilings.

Chapter 3 offers the historical and cultural background related to star ceilings, as well as the environmental and ecological context of the two star ceiling sites examined for this thesis, including a brief survey of the scholarly literature pertaining to Navajo star ceilings.

Chapter 4 describes the methods and data-collection procedures used in this thesis to acquire data at the two star ceiling sites that were examined for this thesis. In this way, the various data-collection methods are defined and summarized.

Chapter 5 presents the results of the data-collection efforts. These results are compelling and enable this thesis to add to the scholarly research and scholarly conversation regarding star

ceilings. Included here are tables and figures utilized to present the data retrieved from the two sites.

Chapter 6 provides the overall analysis of the data results, as well as the synthesis of the data collected via the data-collection techniques used for this thesis project. The various implications of the evidence found and recorded at the two star ceiling sites are explored in detail.

Chapter 7 closes this thesis with a conclusion describing the ramifications of the results and analysis of this research project, together with a section providing suggestions for further research and a section presenting the limitations of this thesis.

A Definitional Note

Throughout this thesis the words “conservation” and “preservation” are used. These terms can carry multiple meanings in different contexts, and they often appear together here because I understand them as functioning in tandem. For the purposes of this research, therefore, “conservation” refers to all the actions a person or organization takes to ensure the long-term preservation, care, and access to items of cultural heritage, whereas “preservation” refers to the act of caring for cultural heritage items through preventive measures that lengthen an object’s life and increase accessibility for researchers and the general public (Conservation Center for Art & Historic Artifacts 2026). Put simply, conservation may be considered the proactive action to stabilize and repair objects, while preservation is the non-invasive approach to minimizing and preventing damage to a site or an object like rock art (Museum of Ontario Archaeology 2026).

Chapter 2: Theoretical Background

Theoretical Considerations

This thesis focuses on a novel set of star ceiling research techniques and analyses that can support a new type of hermeneutics, or set of interpretations, related to rock art studies in general and Navajo star ceiling research and star ceiling phenomena in particular. My research interweaves a few different avenues of investigation to develop some further meanings associated with star ceilings, their etiology (cultural origins), elemental composition, and sacred use, as well as some semi-experimental and digital ways to examine emerging methods for potentially restoring, conserving, and preserving these fragile artworks. In this way, this study is a multi-methods approach to expanding our general understanding and our attempt to care for these special artworks. In some sense, too, this study is meant to examine and assess the appropriateness and effectiveness of emerging technologies in supporting rock art research.

The research and data collection effort primarily employs a modern analytical technique, portable X-ray Fluorescence (pXRF), to explore a new understanding of the chemical elements of these significant artworks. I also experiment with emerging technologies, like Artificial Intelligence (AI) and Virtual Reality (VR), to examine the potential efficacy, suitability, and appropriateness of digital restoration/reconstruction and preservation of these fragile artworks. This thesis also employs standard fieldnotes and photographic techniques as well as a pollen analysis of a grinding stone found at one of the star ceiling sites, and consultation with professional conservators.

I investigate Navajo star ceilings found at two different and distinct sites in New Mexico, one located on private land, near the Navajo Lake area, and the other on Bureau of Land

Management public land, within the Rio Puerco Field Office unit. Because of restrictions in funding and in access, as well as permit restrictions related to the BLM site, not all of the techniques described here are used at both sites. Rather, one technique (pXRF) is used at both sites while the other techniques are used at one site or the other. The data-collection techniques for this study of Navajo star ceilings are built around answering the following broad question: How can combining traditional rock art research techniques, such as fieldnotes and photography, together with modern technologies, like portable X-ray fluorescence (pXRF) pigment analysis, Artificial Intelligence (AI), and Virtual Reality, provide new insights into the material choices, ritual painting processes, and digital research and preservation of Navajo star ceilings, and what does this reveal about the potential usefulness of emerging digital tools for documenting, conserving, and preserving ancient rock art?

See Figure 1 for an example of a star ceiling pictograph.



Figure 1: Red Star pictograph from a Star Ceiling (Site 2). Photo taken by author.

XRF and Rock Art

X-ray Fluorescence spectrometry is a technique that has been refined over the last century, allowing researchers to determine the elemental composition of various materials. The process works by directing high-energy photons from an X-ray source toward a specific target. When these photons strike atoms, they displace electrons situated inside the atoms. As the atom tries to re-stabilize itself, other electrons become displaced, emitting energy, or fluorescence, in the process. Because every element releases energy in a distinct pattern, XRF machines are able to identify the unique light signature—a fluorescent fingerprint of sorts—that allows researchers to identify exactly which elements are present in a substance or material (Newman and Loendorf 2005:277). Over the years, this process has been primarily restricted to the lab environment, but the technology has evolved to allow for portable versions of the XRF machine. The portable version is known as pXRF.

XRF analysis in the field of archaeology has been around since at least 1960, when Edward Hall described its potential use and its drawbacks (Hall 1960). The first use of pXRF with rock art was performed in 2005, when Newman and Loendorf used a pXRF machine at several rock art sites in Wyoming and Montana, describing the elemental composition of green pigments and also tracing the source of historic “retouch” on ancient rock art sites (Newman and Loendorf 2005:282). Interestingly, Newman and Loendorf were also able to identify the source of pigment materials through the pXRF analysis.

Since 2005, pXRF has been used at scores of rock art sites, highlighting its usefulness in supporting rock art analysis and interpretation (Andreae et al. 2021; Bedford et al. 2018; Huntley 2012; Koenig et al. 2014). So far, pXRF has not yet been used at a Navajo star ceiling site; thus,

this thesis adds to the scholarly discourse about star ceilings and supports greater articulation of Navajo star ceilings as vital representatives of indigenous-produced sacred art.

AI and Rock Art

AI is having its time in the sun right now. Since the emergence of deep learning in the 2010s, AI is revolutionizing the sciences, and even how science is being done (Wang et al. 2023). Data collection, data generation, data refinement, pattern recognition and deep learning, algorithm production and refinement, hypothesis generation, and experimentation and simulation are just a few areas where AI is dramatically impacting the scientific method (Wang et al. 2023).

With respect to archaeology, AI is being harnessed for site discovery (Sakai et al. 2024), artifact recognition (Anichini et al. 2021), language deciphering (Jiaming et al. 2019), and support with 3D reconstructions (Massimo et al. 2016). In fact, the work by Sakai and colleagues (2024) identifying geoglyphs at Nazca via satellite images is perhaps the most well-known application, at present, of AI's use in archaeology. This was front-page news for weeks!

AI is substantially revolutionizing how rock art research is performed. AI techniques dramatically support rock art recognition and analysis (Horn et al. 2022; Macieira et al. 2025), identification and classification (Horn et al. 2022), and motif extraction and object (iconographic) identification in different geological contexts (Jalondoni et al. 2022). Horn and colleagues (2022) predict that the future of AI approaches to rock art studies depends on the possibilities of theorizing about rock art itself—that in some way, AI applications in rock art studies may be limited by our own cognitive limitations to conceive of rock art creation and use.

Jardim and colleagues (2025) trace the trajectory of AI within rock art research. They note that the long-standing reliance on field sketches and photography is evolving toward a

computational approach of recording rock art capable of automatically reconstructing motifs. In this way, archaeology and rock art studies are at a real turning point. In their words:

[...] AI is not a replacement for archaeological interpretation, but a powerful extension of it. When implemented in a thoughtful manner, these technologies can unlock new layers of meaning in the oldest art forms in the world, deepening our understanding of human history while ensuring its preservation for generations to come. (Jardim et al. 2025:5-6)

For this study, I use AI to support reconstruction and interpretation, and to help support novel ways to think about digital conservation and preservation. In other words, I attempt to use AI to restore/reconstruct and preserve/conserve star pictographs. On top of this, Alex Kashkin, a researcher at MIT, developed an AI technique to restore paintings on canvas (Chu 2025), and, among other approaches, I attempt to test his technique's viability for doing the same with rock art. I also attempt to expand our conceptual limitations by employing AI to support new ways of thinking about rock art production by creating a star ceiling production algorithm.

As of the writing of this thesis, I could find no research regarding AI techniques with Navajo star ceilings.

VR and Rock Art

New forms of digital representations of archaeological sites, including rock art sites, are being investigated vigorously at the present moment, as interest in digital cultural heritage—and the concomitant technology related to digital cultural heritage—evolves and expands (ITN-DCH 2018). Indeed, this is an exciting time for the digital cultural heritage movement.

Photogrammetry approaches to archaeological science have been around since the mid-1800s (Alberz 2001). New methods of digitally capturing sites and landscapes are now supporting 3D and VR immersive experiences (Fritsch and Klein 2018; Wastoby et al. 2012). Though once the domain of the gaming industry, VR is proving to have vast implications and practical use for archaeology as well as public education about archaeology (Rodil et al. 2021).

VR techniques are showing promise with rock art studies as well. Torres and colleagues, using a multidisciplinary approach, exhibit how VR techniques support advancement in methodology in archaeological research and in rock art studies, supporting increased “knowledge transmission and the creation of more robust and coherent archaeological interpretations through sensory perception and historical empathy” (Torres et al. 2024:1).

Additionally, Palonka and colleagues (2023) perform a multi-methods approach to rock art research in Colorado; though they are examining the relationship between culture and environments over time, their research forms a grounding in novel methods to approaching the creation of digital representations of Native American rock art. Using photogrammetry and 3D laser scanning techniques to document a massive petroglyph panel located at the Canyons of the Ancients National Monument, in the Mesa Verde area of southwestern Colorado, their multi-methods digital approach supports both “accuracy and the ability to gather large quantities of data in a short time, at a relatively low cost” (Palonka et al. 2023:6).

Again, VR methodologies have not yet been used at Navajo star ceiling sites.

Some Final Thoughts on Theoretical Orientation

This focus of this thesis is on a particular form of esoteric and rare type of Native American rock art. Therefore, this study’s attention is on representational art—objects that are in the domain of the Humanities and Art History, as well as Anthropology. The various approaches

I use to examine this art form are rooted in the processes of both scientific discovery and cultural/artistic discovery. As a result, I will at times move between the cultural/artistic and the scientific, between the Humanities and the Sciences. I will, to use the phrase of C.P. Snow, attempt to bridge the Two Cultures—the divide between the sciences and the arts (Massey 2019).

In this vein, Carolyn Boyd has laid the groundwork for a deep interdisciplinary multi-methods research process with the documentation and interpretation of Pecos River Style pictographic rock art in southwest Texas and Coahuila, Mexico (Boyd and Cox 2016). In particular, Boyd, with her background as an artist herself, and through her Shumla Archaeological and Education Research Center, “examines the role of hunter-gatherer artists as active participants in the social, economic, [religious-spiritual,] and ideological fabric of the community, and the function of art as communication and a mechanism for social and environmental adaptation” (Boyd ca. 2025). In this way, Boyd comes at ancient rock art utilizing various means of analysis, both scientific and humanities-oriented, and she has discovered that by expanding the approach to rock art analysis, scientists can in fact gain more understanding of the underlying meanings associated with ancient rock art iconography (Boyd et al. 2023).

Though lacking the sophistication of Boyd’s lab, this thesis mirrors Boyd’s interdisciplinary multi-methods approach to rock art studies. By acquiring as much data as possible, via multiple data-collection techniques, I propose that we can discern new patterns of meaning that will support new interpretations for Navajo star ceilings, as well as new ways to think about conservation and preservation for these artworks.

My real aim is practical in that ultimately it is my hope that identifying and understanding these artworks through various techniques like pXRF, AI, and VR will amplify our understanding of star ceiling production, use, and cultural meaning. It is through these

methods that we may be able to not only know more about these artworks but also to formulate and develop a potential preservation and preventive conservation plan, ensuring that these rock art sites continue to exist for generations to come. On top of this, we can assess whether emerging technologies can practicably assist in this venture.

Importantly, I do not want to collect data simply for the sake of expanding academic knowledge; rather, I sincerely hope that these efforts can be used to benefit the Navajo people at large and their engagement with their own history and archaeology. Work will be done, then—based on this thesis—to support public archaeology in the Navajo community via providing the Tribal Historic Preservation Office (THPO) with the means to take part in the VR aspects of this research, which are primarily focused on the star ceiling found on BLM public land. I plan to offer the THPO and the Navajo Museum VR headsets and the concomitant digital material to be able to access the VR components of this thesis—if the THPO agrees. This will provide the Navajo people an opportunity to virtually visit an important Navajo cultural site, reducing barriers and increasing access to an otherwise remote location.

Important Reflections on Ethics and Sovereignty

This is the exact point where critical issues of ethics and Navajo tribal sovereignty come into play. Though this thesis is researched and written from an intentional stance of cultural humility, in the way that Colwell-Chanthaphonh and Ferguson describe it (2004), the truth is that the Navajo cultural tradition and the Navajo people themselves may not agree with the conservation or preservation of their sites in the way that it is examined here. And though the pXRF and other forms of analysis are inherently non-destructive, the Navajo people may not find these techniques appropriate for research vis-à-vis their own sacred rock art.

Tamara Billie, in her University of Maryland Cultural and Heritage Resource Management master's thesis, *Working Together, Gets Work Done*, describes how Western forms of archaeology, rooted in colonialism, historically reduced tribal members to research subjects thereby robbing them of their voice (2021:1-21). She therefore advocates that Western archaeologists engage in an Indigenous Archaeological framework wherein tribal members are invited to offer their voices and perspectives on archaeological research. Billie emphasizes that an "Indigenous methodology prioritizes contributing to a body of knowledge, current, and past, while respecting Indigenous people's needs and interests" (2021:18).

I was familiar with, and indeed inspired by, Billie's work before beginning this thesis, and although this project was conducted independently to satisfy the degree requirements at the University of Maryland and did not trigger federal regulations beyond the approval of an Archaeological Resources Protection Act permit by the BLM, I nevertheless made a sincere effort to seek guidance from Navajo scholars.

Whitley emphasizes that rock art forms part of a broader cultural landscape whose significance is deeply connected to descendant communities, highlighting the ethical value of consultation even without a legal requirement to do so (Whitley 2001:21). While I was unable to establish formal and meaningful communication with Navajo scholars—because they did not respond to me—I did speak with several Navajo community members regarding geographical context, cosmological movements, and geological characteristics relevant to the rock art examined for this study. I also consulted with several ethnohistorical sources to attempt to honor the Navajo perspective (Griffin-Pierce 1992a; Haile 1947; Kluckhohn 1944; Zolbrod 1984).

The fact that I could not access a real and consistent Navajo view regarding this project, especially the methodologies represented here, brings up an interesting set of questions rooted in

something of an ethical dilemma that I encountered, and I think these questions can form the basis for future research: If a Western researcher seeks Indigenous participation and does not, or cannot, obtain it, what should their next steps be? Has the ethical obligation to invite Indigenous voices been met simply by extending the invitation itself, or does responsible archaeological practice require additional forms of accountability when collaboration is not possible? What should this accountability look like? More broadly still, should Western researchers study Native American art and artifacts at all, particularly when issues of cultural patrimony arguably transcend laws pertaining to land ownership and land status? What are the real limits of Western interpretation of sacred Native American artworks, especially when Indigenous communities are reluctant to, or cannot, engage in the research?

These questions are not simply based on my discomfort with studying Navajo artworks without the direct guidance or participation from the Navajo people themselves. Through this thesis project I have become aware of the broader conversation outlined by scholars such as Atalay (2012) who, like Billie (2021), advocates for research models that do not recreate colonial power dynamics and undermine Indigenous sovereignty. Atalay sees archaeology as an opportunity to view archaeological research as “with, by, and for” a community instead of “doing research ‘on’ or ‘about’ them” (2012: 63).

To be fair, time was a factor for me. I simply did not have adequate time to develop a longstanding and trusting relationship with a Navajo scholar, as the time constraints for this thesis were real and restrictive. But leaving the time constraints aside, I attempted to initiate communication but did not receive a direct response from Navajo scholars regarding this project, and I would have liked to. To be honest, this dynamic created a real internal conflict for me. As Laluk (2017) and Billie (2021) both propose, I truly wanted to do a collaboratively-engaged

project, one that elicited genuine tribal participation, but found that in reality I could not. Even so, and as mentioned, I intend to provide some of the materials from this study to the Navajo THPO (via the BLM), with the sincere hope that they will review the work and offer guidance or a viewpoint.

I thus encourage readers of this thesis to engage with Navajo perspectives on the material described here. Critically, the Navajo view of their own culture and history, especially as it relates to star ceilings, is vitally important. I have attempted to exercise caution in all aspects of this thesis, but the Navajo tribal voice will be a vital counterweight to my largely Western approach to delineating and describing the results of my work. That is to say, the final word on Navajo star ceilings remains both in the hearts and minds of the artists themselves and the Navajo tribal and cultural tradition.

Chapter 3: Historical and Cultural Background with Environmental Setting

Historical Background

Star ceilings are a type of Native American pictographic rock art style characterized by cruciform icons that symbolically represent the stars of the night sky and are generally found throughout the Four Corners region of the United States. According to the United Nations Educational, Scientific and Cultural Organization's (UNESCO) *Portal to the Heritage of Astronomy*, there are approximately 80 known star ceiling sites in North America (2025). Star ceilings are attributed to the Navajo people (the *Diné*) because they are largely observed on traditional Navajo/*Diné* lands. This pictographic rock art style is typically witnessed in caves, at spring sites, underneath cliff and/or rock overhangs, and sometimes at the intersection of rivers. Known to contain deep spiritual significance and power for the Navajo people (Chamberlain and Schaafsma 2005), star ceilings are described in the archaeological literature beginning in 1951, with De Harport's description of Navajo star ceilings in Canyon De Chelly (De Harport 1951). Considerable research has been conducted to document and explore particular star ceiling sites, or groups of sites, especially at Canyon de Chelly, where the majority of all known star ceilings—close to 70 percent—are located (Chamberlain and Schaafsma 2005; UNESCO 2025).

There are some wonderful written accounts from conquistadors and early Spanish explorers, during the time of the Spanish incursion into New Mexico beginning in the 1500s—also known as the Spanish Entrada—of encounters with pictographic stars and other hand-drawn stars produced by Native American groups for various reasons. For example, Alvar Nunez Cabeça de Vaca's 1542 "La Relacion" and Pedro de Castaneda de Najera's 1542 account of the

Coronado expedition are narratives presented in *Original Narratives of Early American History: Spanish Explorers in the Southern United States 1528-1543* (Jameson, 1953) that describe stars being used for protection in general, and as a type of symbolic protective barrier to prevent the Spanish from entering sacred spaces. Indeed, Castaneda de Najera was warned not to cross a line of stars at Acoma Pueblo, which provides something of a window into the symbolic value and, perhaps, power of the artistic representations of stars. Crucially, the very first description in the historical literature of something akin to a star ceiling, is found in Castaneda's account of the Coronado expedition, and, relevant to this study, this cruciform star symbolism is witnessed at a spring site:

For at a spring, which was in the plain, near Acuco [Acoma Pueblo] they had a cross two palms high and as thick as a finger, made of wood with a square twig for its cross piece, and many little sticks decorated with feathers around it, and numerous withered flowers, which were the offerings. (Hodge and Lewis 1953:384)

The Antonio de Espejo and Juan de Oñate expeditions serve as vital examples of early observations by Europeans of encounters with Native American-produced star iconography, particularly among the “Querechos,” or Apache people, some of whom became distinguished as the Navajo people (Bolton 1953:183; cf. “Apache de Nabajo” in Benavides’ *Harvest* qtd in Morrow 1996:57). As Alonso de Benavides noted in his *Harvest*, these people were known as the “Apache de Nabajo,” which is translated to mean “big planted fields” (Benavides qtd in Morrow 1996:62). This designation was significant, marking them as distinct from other Apachean groups specifically because of their presumably unique use of agriculture.

Also, Roque Madrid's military journal, written at the time of his campaign against the Navajo in 1705, contains some of the earliest recorded examples of star iconography being created and used by the Navajo people (Hendricks and Wilson 1996). It may be significant that this account was produced during a time of war, for themes of protection and star power seem deeply connected to star representation and symbolic star use (Chamberlain and Schaafsma 2005:94).

Star Ceilings in Navajo Culture and Myth: A Brief Literature Review

Naturally, and importantly, stars and star ceilings feature prominently in the Navajo mythological corpus. The Navajo Creation Story, known as *Diné bahane'*, as presented in Paul Zolbrod's (1984) literary rendition of this important creation narrative—approximating the traditional Navajo storytelling style—is a source book for examining star iconography, their ritual use, and the sacred stories that undergird the creation of the stars and their various meanings. This book contains stories that are absolutely sacred to the Navajo people, and it provides a launching point and roadmap, or foundation, for any investigation into Navajo culture.

Von Del Chamberlain offers a wonderful story of the creation of the heavens and of the stars in his *Native American Astronomy* (2000). I quote Chamberlain at length here because this version of the creation of the Navajo stars and constellations is compelling and distinct, and it serves to amplify the general theme of the Emergence Story narrative:

According to some Navajo, the sun was formed from a perfect piece of turquoise and the moon from a perfect piece of white shell. Each was given spirits for movement, feathers for flight and crystals for light. Pieces of crystal remained—and three of the Holy People—the Fire God, known as Black God, First Man, and First Woman—placed these

on a buckskin in pleasing patterns to represent the principles that would bring long life and happiness. These would be used to benefit Earth Surface People, to help them find their way, always maintaining balance and direction. They would create stars to provide seasonal and nightly markers for agricultural, hunting, and ceremonial activities. The Holy People began putting up the stars. They placed the Fire Star in the north. To one side they put Revolving Male, and to the other side Revolving Female. Coyote, the Trickster, was wandering about as always. He noticed the sky start to change, and thought to himself, "I must find out what is going on." So off he ran to find where the sky changing was taking place. He approached as the Fire God was putting up First Slim One. He watched as Black God put his own stars, Dilyehe, near First Slim One. He moved in closer as Man With Legs Ajar, then First Bog One were put up. Now he was right among them. He asked to put his own star in the sky. Reluctantly, knowing the usual outcomes of projects Coyote got involved in, they allowed him to place one star in the south. This was tiring work. As the others rested, Coyote thought, "This is taking much too long." He seized one end of the blanket containing the crystal stars, and with one swift motion flung them into the sky. He had done it again! Where order was intended, he had succeeded in bringing disorder. That explains why we find the stars as they are today. A few are in proper patterns, symbols of how we should live our lives, while the rest are just scattered about, the way Coyote threw them up there. (279)

Another important Navajo myth is the *Ajilee* myth, which explores the destructive aspects of the lust for sex and hunting bloodlust. As recounted by the Navajo elder Slim Curly in Father Berard Haile's, *Love-Magic and Butterfly People* (1978), this story contains a specific reference

to a star ceiling site and highlights a deep connection to the Jemez Pueblo. The Ajilee myth serves a crucial function in healing, as it is used in medicine chanting ceremonies to reduce the destructive power of love lust and bloodlust, while also using hunting magic to defeat enemies, and helping a patient return to a state of balance to “walk in beauty.”

Of particular note is Jeff King’s war ceremonial, “Where the Two Came to Their Father,” as presented by ethnologist Maud Oakes (1991). It describes the Navajo Creation myth with an especial focus on the Hero Twins, the Navajo cultural guardians and saviors. Significant to star ceiling imagery is the representation of King’s sandpaintings that are important examples of Navajo “star” symbolism (Figure 2). This ceremonial, in which its distinctive sandpaintings played an important part, was offered to protect “young men who had either volunteered or been drafted into the Army” during World War II (Oakes 1991:10). Again, the themes of protection and the defeat of enemies are prominently witnessed in King’s myth, especially in the characters of the Hero Twins and their defeat of the monsters; the associated sandpaintings are symbolic representations of this mythic story. These elements are also playing out, so to speak, in the movements of the night sky (Oakes 1991:21). As it is above, so it is on earth.



Figure 2: Plate XIV Sandpainting by Jeff King of the Sun setting to the right and the Moon rising to the left. The hogan doors all face East toward the rising Sun. (Oakes, 1991). Copyright Princeton University Press. Reproduced with permission from Princeton University Press.

As Hosteen Klah, Navajo Ceremonial Chanter puts it—via Franc Newcomb, the famous Navajo anthropologist and friend of both Klah and Mary Wheelwright, “all the laws our people will need are printed in the sky where everyone can see them [...] The commands written in the stars must be obeyed forever” (qtd. in Britt 1975:101).

Apropos of Navajo sandpaintings in general, there is a longstanding argument posited by Schaafsma that traditional rock art style and techniques literally transitioned into sandpaintings in the Navajo culture, as the Navajo had to become more mobile with the incursion of the Spanish following the Second Pueblo Revolt in 1692 (Chamberlain and Schaafsma 2005; Griffin-Pierce 1992; Schaafsma 1963). Put simply, via this perspective, rock art evolved into sandpainting among the Navajo. This argument is not only compelling for its research value but

also because it highlights the cultural and, indeed, geographical transition from one phase of living associated with a certain geography to a newer phase related to another geographical center—that is, a movement from the eastern areas of *Dinétah* (traditional Navajo homeland) to areas more western, to the current location of the Navajo Reservation. This migration is somewhat complicated and has several different phases that are worth further examination, especially when seen face-to-face with star ceilings.

Chamberlain and Schaafsma described this transition well, and so does David Brugge in his exposition of Navajo Architecture (1968), but Campbell and Forton (2023) offer a succinct and compelling description:

Diné tradition identifies the rugged canyonlands along the upper San Juan River drainage of northwestern New Mexico and southwestern Colorado as *Dinétah*—that is, “among the Diné”—the place where Navajo people came to be following their emergence into this current world ... [and] firmly established as the principal locus of Diné settlement during the seventeenth and eighteenth centuries. [...] The arrival of Spanish settlers in New Mexico circa AD 1600 marked a dramatic restructuring of the Southwestern world. [...] Following [...] [the Pueblo Revolt and Spanish re-incursion,] the [...] 18th century appears to reflect the movement of many Navajo families to more secure areas. Growing reliance on livestock, particularly sheep and goats, afforded Diné groups greater mobility during this period. ... By AD 1800, the primary locus of Navajo population had shifted to the west, although the ancestors of today’s Eastern Navajo families continued to live in and around the old Diné tah heartland. (44)

Furthermore, and in addition to the above, activities associated with witchcraft and stories related to magic and witchcraft are vital to understanding both the power of star ceilings and the potential locational placements of these artworks. In *Navajo Placenames and Trails of the Canyon de Chelly System, Arizona*, Stephen Jett's (2001) research on star ceilings presents the argument that star ceiling uses are grounded in witchcraft and magic. The Navajo are generally understood to be extremely leery of witchcraft and magic, but harnessing star power can be thought of as a type of magic to enhance human capability, especially for protecting the Navajo people from "aliens" (Chamberlain and Schaafsma 2005). Klyde Kluckhohn offers some extremely useful insight into Navajo magic in his volume, *Navajo Witchcraft* (1944). These ritual activities can be considered part-and-parcel of ceremonial efforts to make star power tangible in the earthly realm.

Known Locations and Dating and Other Reflections

From what is written in the literature regarding star ceilings, there are approximately 75-100 known star ceiling sites (Chamberlain and Schaafsma 2005). UNESCO puts it right at 80 known sites in North America (2025). As mentioned, they are typically found at the intersection of rivers, under cliff overhangs, inside spring sites, inside caves, and other areas near water and protected from the sun (Figure 3). The icons on display at star ceiling sites are deeply rooted in the mythological understanding of creation and of the night sky. It is possible that the star ceiling is a ritualistic tool that was used to protect the Navajo people from "aliens," or enemies, and that the star power available at star ceiling sites could be harnessed for protection—even protection from rock falls (Chamberlain and Schaafsma 2005).

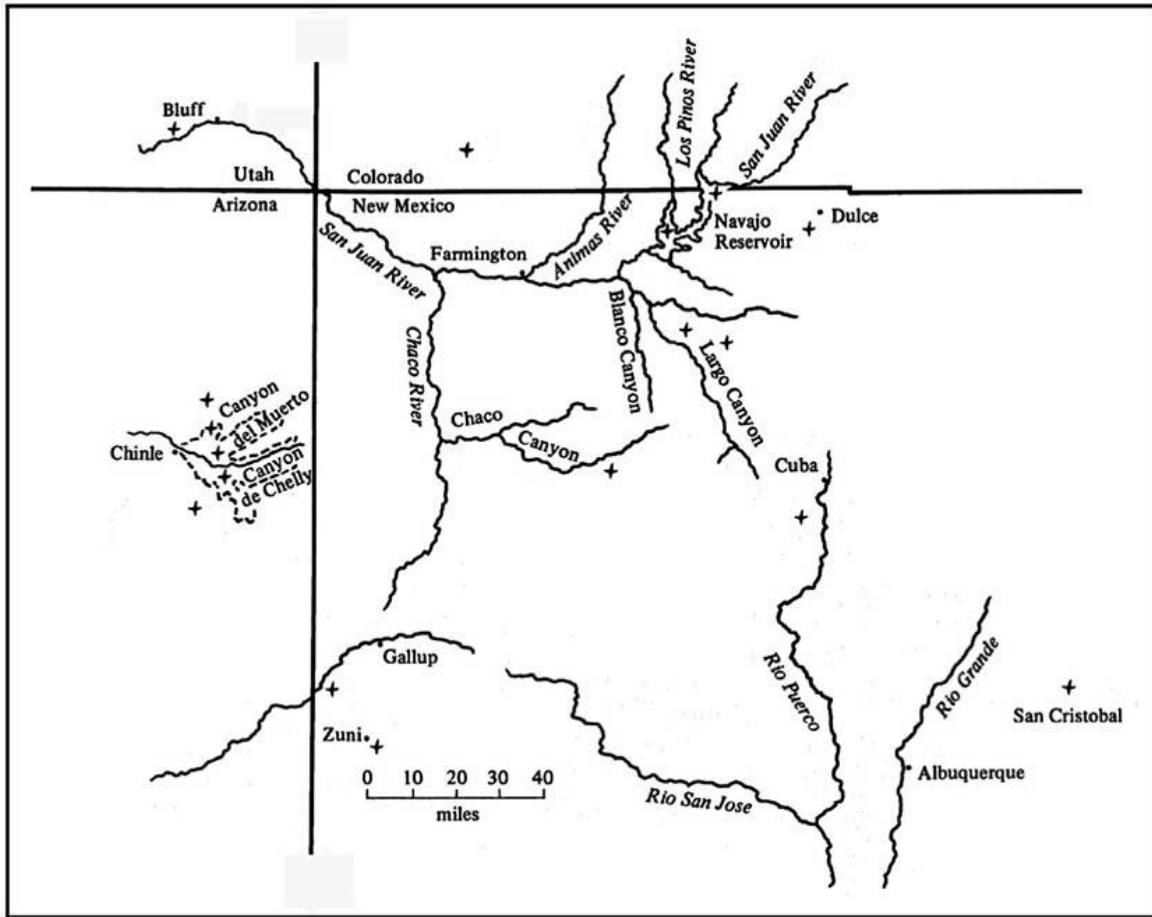


Figure 3: Generalized map of star ceiling sites in New Mexico. Chamberlain and Schaafsma (2005:81). Reproduced with permission from Ocarina Books.

Some associational dating at a star ceiling site (known as Site 2 in this study) places their temporal etiology to sometime before 1520-1660 AD (Christian 2012:80), the time period when the Spanish enter the region and begin to explore and colonize the land and the indigenous people who live there. The artistic technique, or style, appears to have moved west with the Navajo when they geographically transitioned from eastern areas of the *Diné'tah* to the west, where the Navajo Reservation is now located; that is to say, eastern examples of star ceilings most likely predate western ones. Moreover, Canyon de Chelly's star ceilings located in northeastern Arizona, as well as those at Canyon Del Muerto and other sites to the west, may be

the newer varieties and examples of star ceilings and, in some ways, representative of the most refined samples of these special artworks.

As mentioned, it is also possible that with this transition into the Western areas of the Navajo geographical range, rock art began to transform into sandpainting—that as the Navajo became more mobile, when there was less ability to gain access to traditionally sacred sites, the Navajo, by necessity, had to transform their sacred rock art into sandpainting to keep the traditional ritualistic techniques alive and viable (Chamberlain and Schaafsma 2005; Griffin-Pierce 1992; Schaafsma 1963).

Incidentally, and importantly I think, nowhere in any of the literature pertaining to Navajo star ceilings is found the Navajo word, or words, for star ceilings themselves. That is to say, these wonderful and beautiful artworks are never described using their Navajo formal name. This fact speaks to many things, one of which perhaps must be thought of as the Anglo approach to studying these artworks, or also perhaps the Navajo resistance to having these artworks studied. Either way, it seems clear that the mention of these sacred pictograph sites in academic texts ignores Navajo sacred nomenclature, a practice that may in fact reveal a potential tendency in anthropology and rock art studies itself to decontextualize and objectify Native American art. This fact invites a critical reading of the ethnological and rock art studies record pertaining to star ceilings. Much more can be said about this dynamic, and should be said, but unfortunately it is outside the scope of this thesis.

My sense, in the spirit of Wittgenstein (1922), is that in order to understand a thing we must know what to call it, it must have a name; so it may be, perhaps, that until we know what, or how, the Navajo people call these artworks and sites, there may be no way to truly comprehend them from our Western-centric perspective.

The best translations I could find for “star ceiling,” as provided by OpenL’s English-to-Navajo translator are: “*sq’ bil dah naashá*,” or “I am walking around with a star/I am walking among stars” (OpenL Translator 2025).

Mud Balls

Worth mentioning is the appearance of mud balls with certain star ceilings. At different sites, one can witness mud ball offerings thrown onto the star ceiling pictographic images (Figures 4 and 5). These mud balls may have twigs and/or beads included within them, intentionally inserted into the mud before the balls are thrown onto the ceilings (Christian 2012).



Figure 4: Wide view of mud ball offerings from a star ceiling site (Site 2). The mud balls are seen as grayish balls or protuberances, with a few pictographs in the upper left portion of the photo. Photo taken by author.

They are thought to be sacred prayers, or gestures of thanks to the ancestors, or perhaps even magical offerings meant to bring about rain (Kluckhohn 1944; Loendorf et al. 2003). They

appear in both Pueblo and Navajo myths (cf. Matthew's *The Mountain Chant* [1997] and Parson's *Pueblo Indian Religion* [1966]). Mud balls offer a fascinating focus for future research, even by themselves, as distinct phenomena in relationship with Native American pictographic artworks.



Figure 5: More mud ball offerings adjacent to a star pictograph at a star ceiling site (Site 2). Photo taken by author.

The Environmental Setting: A Description of the Sites

My main sources of data for this thesis are two star ceiling sites, one found on private land and the other found on BLM public land. I call these sites Site 1 and Site 2 respectively. Both locations are substantial in their own right. Both are also found within traditional *Dinétaḥ* landscapes and can be said to be located right in the middle of the traditional Navajo cultural universe (Campbell and Forton 2023:44).

Site 1

Site 1 is located on private land, in the Navajo Reservoir district of Northern New Mexico, in close proximity to the San Juan River. According to Campbell and Forton (2023), this area was once the traditional homeland of the Navajo, before the Navajo moved south and west toward what is now the Navajo Reservation (44). My review of the New Mexico Cultural Resource Information System (NMCRIS) indicated that this site is not recognized by the New Mexico Historic Preservation Department (NMHPD), as it has not been recorded and is not represented by a site number.

A bit of background for Site 1: Using Polly Schaafsma's seminal 1963 book, *Rock Art in the Navajo Reservoir District*, I encountered this site on a personal field trip to Navajo Lake. Even though she did not highlight this particular site but grouped sites together more generally, the sketch map that Schaafsma provided was an accurate enough guide to lead me to this site's location (1963:4). The site contains two alcoves connected by a ridge of rock. I call them Alcove 1 and Alcove 2, respectively.

Stumbling on this site was very special. Alcove 1 is tucked underneath the main road in and out of the canyon in which the site is nestled. I dropped into the alcove, and right at eye-level was a fallen boulder sheared off from the ceiling, with a star pictograph—one equilateral cross—painted on it. It was a seriously electric moment for me.

Following contact with the owners of the site and an exchange of money to stay at the site and perform thesis research there—the site serves as a Hipcamp, rent-to-stay camping site—I became aware of more stars in the second alcove (Alcove 2) attached to Alcove 1 but obscured by thick brush. Again, this was a special moment. This second alcove is closer to the ground and

can only be accessed by scooching underneath the rock overhang, which at its greatest height is only two feet off of the ground.

With respect to the geology and geography surrounding Site 1, according to Price, “Bedrock exposed in the [region] belongs to the lower Eocene San Jose Formation. During the early Eocene, about 50-55 million years ago, large rivers flowing to the south deposited the San Jose Formation in the San Juan [River] Basin” (2010:101). As such, the geology surrounding Navajo Lake reveals ledges and cliffs of sandstone situated between slopes of mudstone and siltstone (Price 2010). These features are the deposits of the ancient rivers and floodplains from the Eocene period. Additionally, as Price describes it, the San Jose Formation contains a well-known fossil record of early mammals, plants, fishes, and reptiles (2010:101). Following the Eocene period, the San Juan Basin experienced a major uplift, pushing the Navajo Lake region to over 6,000 feet in elevation (Price 2010:103).

Moreover, the entire landscape surrounding Site 1 is witness to a great deal of human culture and human history. For instance, well-known archaeological sites like Aztec Ruins National Monument, Salmon Ruins, Chaco Canyon, and Mesa Verde, are all within proximity to Site 1; the Navajo Nation, the Ute Mountain Reservation, and the Southern Ute Reservation Tribal lands, as well as the Jicarilla Apache Nation, all surround this site or connect to this broader geographical area (Chamberlain and Schaafsma 2005:81; Price 2010:103). This region is so very rich in both culture and history!

Site 1 contains petroglyphs, grinding stones, and some carbonized material. It also contains six star pictographs in total, one in Alcove 1 and five in Alcove 2 (Figures 6 and 7).

In a casual conversation with a local Navajo woman, she told me that this area around Navajo Lake, the area surrounding Site 1—much like Campbell and Forton have noted (2023)—

can be described as the “center of the Navajo world.” She mentioned that some of the “older ones think that the Navajo people are losing their language and culture because of the flooding of that area to make the Lake” (personal communication 2025).



Figure 6: Site 1, Alcove 1. Alcove 1 contains one star. Photo taken by author.



Figure 7: Site 1, Alcove 2. Alcove 2 contains five stars. Photo taken by author.

Site 2

Site 2 is the BLM public land site, located outside of Cuba, New Mexico, about an hour's drive from Site 1. This site is part-and-parcel of a natural spring and alcove/cave site, and it is situated within a large canyon system located at the bottom of a geological feature known as a *cuesta*, or ridge. The natural spring flows throughout the year, providing water for both wild animals and the grazing cattle. The rock canvas for this star ceiling site is comprised of an overhang that has been cut by eons of geological processes to produce a large cavern or alcove.

In contradistinction to Site 1, which exhibits only six stars, Site 2 contains approximately 200 star pictographs, among other pictographic icons and various petroglyphs as well (Christian 2012). The majority of the hundreds of pictographs are painted on the ceiling of the interior of the cave, which measures 100 feet wide at the mouth and 60 feet tall at its greatest height (Figure 8). These pictographs, then, are mostly found at heights in excess of 50 feet—which has fueled some mystery about their creation (Chamberlain and Schaafsma 2005; Christian 2012). However, it must be highlighted that some of the artwork is found at eye-level and can be reached from the ground.

I have had the opportunity to study the pictographs on display at Site 2 in the past (Christian 2012). The research I performed for that study was consistent with a type of historical, mythographic, and thematic perspective that was buttressed by archaeological techniques like radiocarbon analysis to support associational dating and phytolith analysis of various materials. During that in-depth research I did not perform pXRF, AI, or VR techniques. That is to say, though I know Site 2 well, the techniques performed for this thesis are completely novel.



Figure 8: Site 2, cave mouth. Photo taken by author.

Similar to Site 1, Site 2's geological context is located along the southeastern edge of the San Juan Basin. Site 2 is bordered to the east by the Nacimient uplift which, according to the USGS, marks the southwestern limit of the Rocky Mountain province (Christian 2012). It is understood that these two provinces were formed in the Laramide Deformation epoch, that they were created between 95 and 15 million years ago. The rocks contained within the San Juan Basin are interpreted to be comprised of sedimentary rocks, understood by geologists to be created by the continuous rise and fall of sea levels over time. As such, the most represented rock types in Site 2's region are sandstones and shales (Gaudette 2011).

Brittany Gaudette, BLM Geologist, states, “The rock types within the San Juan Basin around the [Site 2] area include (from youngest to oldest): the San Jose Formation, Nacimiento Formation (Tn), Ojo Alamo Formation (Toa), Kirtland-Fruitland (Kkf), Pictured Cliffs, Lewis Shale, Cliff House, and Menefee. Not all of these are witnessed at [Site 2], but they occur throughout the region” (email communication qtd in Christian 2012:30).

Geography, Elevation, and Biota for Both Sites

Both Site 1 and Site 2 can be said to be found within the broader region known as the Colorado Plateau. This region can be generally understood to represent the area comprising the Four Corners (Price 2010). Site 1 is found at 7,151 feet elevation and Site 2 is found at 7,033 feet elevation. The ecological biome represented at these two sites is known as Pinyon-Juniper Woodland, which is widespread throughout the Colorado Plateau. The Pinyon-Juniper Woodlands in New Mexico are dominated by the pinyon species of plant, *Pinus edulis*, and the juniper species of plant, *Juniperus monosperma* (Grahame and Sisk 2002). Ponderosa Pines are evident at both Site 1 and Site 2 as well. These Ponderosas stand tall against the backdrop of the lower Pinyons and Junipers. Precipitation is very low in the Pinyon-Juniper Woodlands, about 10-15 inches per year, and these species have evolved drought and cold resistance (Grahame and Sisk 2002).

With respect to Site 1, the large sandstone boulders found in the San Juan Basin predominate the landscape here. These boulders are huge in size and packed tightly together, making it difficult to traverse the landscape, but they offer a lot of places to hide from the sun and from enemies and wild animals in naturally made nooks and crannies. It is easy to get disoriented and lost in the maze of these sandstone boulders that comprise the natural setting surrounding Site 1. Additionally, the area around Site 1 exhibits an abundance of alcoves and

hidden cavations and wash-outs, many of which must have served as habitation and/or camping sites as well as sites to conduct certain types of warfare. Much of this landscape is now privately owned or owned by oil companies who keep automatic rocker-horse oil pumps operating 24/7/365; so, the landscape moans and echoes a low-level hum emanating from these pumps.

Likewise, Site 2 is completely dominated by sandstone boulders, but they do not choke the landscape. Therefore, the area surrounding Site 2 is easier to walk around in. Too, Site 2 sits within a Juniper-dominated subsection of the Pinyon-Juniper Woodlands, which contains large sections of sage-dominated open savanna. (Site 1 is not at all representative of sage-dominated savanna.) These portions of savanna offer few of the closed-canopied stands which are seen at other Pinyon-dominated subsections. Because of overgrazing, the sections of open savanna comprising the Juniper-dominated Pinyon-Juniper Woodland ecosystem at Site 2 are choked with big sagebrush (Christian 2012). In some places near Site 2, I wear snake chaps at certain times of the year!

A word about site records: As mentioned, Site 1 is not indicated in the New Mexico Historic Preservation Division's (NMHPD's) site management system (the New Mexico Cultural Resource Information System, or NMCRIS) and is therefore not represented by site files or a site number.

Site 2, however, does have a site number—it is known by NMHPD as LA109030, in NMCRIS. Site 2 contains both Historic and Prehistoric archaeological components. The following description is a summary of Site 2's archaeological inventory form as provided by NMCRIS: Site 2's boundaries are clearly defined, and they are estimated to be 1,200 square meters. This site is characterized by alluvial, aeolian, and colluvial soils. Shovel tests and exposures in nearby arroyo cuts confirm subsurface deposits and stratigraphy. Archaeological

deposits extend to approximately .45 meters in depth. The artifact assemblage is diverse, consisting of hundreds of items that exhibit centuries of occupation by various distinct culture groups, including prehistoric Ancestral Pueblo groups and Navajo groups, as well as historic homesteaders, among others, spanning the time-period from 1100 to 1945 AD. Due to its high research potential and the integrity of cultural layers, the site is considered eligible for the National Register under Criterion D. (See Appendix 1 for the full Archaeological Inventory Form.)

The very first thing to notice in the Archaeological inventory report for Site 2 is that it does not mention the pictographs, petroglyphs, or mudballs that are found throughout this cave! It's as if the surveyors either did not look up, or they discounted the rock art completely, not considering it to be of real archaeological significance.

It is also important to mention that I did some analysis of the archaeological material described above in a work performed in 2010-2012 (Christian 2012) to attempt to understand, among other things, some of the cultural activity associated with this star ceiling site. What I found then was that the activity associated with Site 2 can be understood to be ceremonial in nature and could have associations with magical rites to repel the Spanish as they were moving into the region during the Spanish Entrada (1540s and afterward). These rites included rock art production, mud ball production, and other ceremonial activities, all in line with a type of weather magic used to harness the forces of nature to drive off the Spanish intruders (Christian 2012:191-193).

Chapter 4: Methods

A Word to Begin

Considerable research has been conducted to document and explore particular star ceiling sites, or groups of sites—especially at Canyon de Chelly (Chamberlain and Schaafsma 2005)—as well as to attempt to understand the historical, cultural, pragmatic, and thematic functions and uses of star ceilings (Christian 2012). As yet, however, aside from radiocarbon dating and other associational dating techniques and general inventorying of the pictographs found at star ceilings (Chamberlain and Schaafsma 2005; Christian 2012), pXRF, AI, and VR analyses of star ceilings have not been performed.

For the purposes of this study, the use of these specific techniques: 1) supported determination of the elemental chemical constituents of the pictographs themselves, potentially leading to greater understanding of their production and use; 2) helped to determine if emerging technologies can support further interpretation, conservation, and preservation of these sacred sites; and 3) assessed whether emerging technologies are a viable and practicable vehicle to documenting and analyzing rock art sites in general and star ceiling sites in particular.

The approach I use for this thesis is non-destructive to the artworks being analyzed, though a pollen analysis procedure is performed on a mano found near the star ceiling found on private land.

Methods of Research

My methods for this thesis are consistent with a multi-methods approach, akin to Carolyn Boyd's work with the Pecos River Style rock art in Texas (Boyd and Cox 2016; Boyd et al. 2023). I do not follow her procedure exactly, simply because I do not have the lab or the

resources—as she uses microscopy and stratigraphic analysis intertwined with dating techniques and other extremely complicated approaches—but I do follow the spirit of Boyd’s work in that I braid together various data collecting procedures, thereby “weaving together archaeological science [...] to unravel those messages [from the past witnessed in the art] and further our knowledge of the people who created these significant murals” (Boyd et al. 2023:14).

I appreciate Boyd’s work because she and her colleagues bring to bear an entire arsenal of scientific and humanities-oriented research methods, including consultation with indigenous groups, to approach ancient rock art. Boyd is trained as an artist so she comes at this work with an artist’s eye (Boyd and Cox 2016), and she uses Kubler’s book, *The Shape of Time*, first published in 1962, as a theoretical guidepost for not only examining changes in art over time, but for keeping our eyes open because “everything about [the art itself] deserves our attention” (qtd. in Boyd et al. 2023:14).

In this spirit, research activities and research methods used for this thesis include obtaining research permissions for both sites; doing background research; documenting both sites with fieldnotes, sketches, and photography; analyzing pollen from one site; conducting analyses using pXRF, Artificial Intelligence, and Virtual Reality; and consulting with conservators. It must be emphasized that the work I perform here is non-destructive to the artworks being studied, and the approach I use as a non-Navajo person is intentionally rooted in a responsible, ethically-framed set of activities with cultural sensitivity at the root of my research strategy.

Research Permissions at Site 1 and Site 2

Site 1 is located on private land. This location serves as a Hipcamp rent-to-stay camping site. Research was permitted at this site following contact with the owners of the property. I

maintained regular contact with the owners to update them on research activities performed there, ensuring good communication while also offering the owners the findings and results of the research.

Site 2 is found on BLM public land. The BLM unit responsible for Site 2 is the Rio Puerco Field Office, whose central base of operations is located in Albuquerque, New Mexico. Generally speaking, the Rio Puerco Field Office provides oversight of over 1 million acres of public land spanning a large portion of Northwest New Mexico (Bureau of Land Management ca. 2025). The Cultural Resource Division of the Rio Puerco Field Office is under the leadership of BLM Archaeologist, Michael Merritt.

In order to conduct research at Site 2, an ARPA (Archaeological Resources Protection Act) Permit was obtained from the BLM. The ARPA Permit secured for this thesis outlines the acceptable research parameters related to Site 2. In this case, Survey and Recordation activities are permitted at Site 2 via this ARPA Permit, and these include non-destructive pXRF analysis, digital reconstruction and digital analysis, and VR digital recordation activities. Michael Merritt, Rio Puerco Field Office Archaeologist, is the BLM point of contact for research conducted at Site 2. (See Appendix 2 for the ARPA Permit.)

Background Research

In order to do background research through NMCRIS, I submitted an application to the Archaeological Records Repository via the New Mexico Historic Preservation Division. This application was accepted and access to NMCRIS was provided to me in August 2025. I obtained archaeological site inventory data from NMCRIS pertaining to Site 2, including a radius search to identify comparable and nearby recorded sites. I also examined associated historical map data and related contextual records to support this research. NMCRIS was invaluable for this thesis,

offering site location information, geographical understanding, and historical and archaeological data, among other things.

Moreover, ethnohistorical literature pertaining to both the Navajo people and to the rock art of the American Southwest was consulted and heavily relied upon to form the cultural, historical, and archaeological lenses with which to examine Site 1 and Site 2. This material forms the anthropological and historical foundation to understand the artworks found at these sites.

Fieldnotes and Sketches

Fieldnotes and sketches were made at each site and alcove. These include measurements and pictographic orientation, as well as compass orientation, elevation, and other data.

Site 1 is somewhat easier to record with fieldnotes and sketches because it is a smaller site. Site 2 is a very large site containing hundreds of artworks. Since Site 2 was recorded in the past with detailed fieldnotes and sketches (Christian 2012), the fieldnotes and sketches produced for this study were strictly focused on a general rendering of the site, with extra attention paid to those individual pictographs that were analyzed using pXRF. Put simply, at both Site 1 and Site 2, exact measurements were made of each analyzed pictograph and hand-recorded.

What's more, and especially at Site 1, Alcove 2, where there seems to be a recognizable star pattern—perhaps highlighting the artist's representation of a constellation—the placement of each pictograph is oriented to the other pictographs in the fieldnotes highlighting this potential orientational pattern.

Field Photography

Digital photographs were taken of each respective site and alcove. These helped to document and exhibit each site and the visual context of the artworks themselves. In addition, each individual pictograph that was analyzed utilizing pXRF was photographed to support data analysis and interpretation. This procedure also helped to catalogue the analyzed pictographs.

Digital field photography is useful for this thesis for several different reasons, but it can also support further investigation of these pictographs in the future, because it can highlight patterns in the artworks' individual production that might go unnoticed. For instance, at Site 2, one of the pictographs is most likely painted by the artist's finger. In this case, we can further analyze the photographs in the future to determine if it was finger-painted, etc.

Pollen Analysis of a Mano from Site 1

Site 1, Alcove 1 contains one pictographic star. Situated on the floor of the alcove immediately adjacent to this single star pictograph sit several manos, or grinding stones. These grinding stones were used to process plants, seeds and sometimes animal matter, and this material may remain on the surface of the mano, giving us a glimpse into what foods or other items were ground/processed with the mano.

Dr. Linda Scott Cummings at the PaleoResearch Institute was contracted with to perform the pollen analysis from one mano sample at Site 1, Alcove 1. Under Dr. Cummings's direction, one mano was identified for this procedure, and after analysis it was returned to the site. This procedure was performed with the permission of the landowners. It's important to note that this mano is spatially associated with the pictograph, but it is not necessarily temporally associated with the pictograph. Even so, the pollen material found on the mano may elucidate pXRF data or other data associated with Site 1.

The pollen analysis, as directed by Dr. Cummings at her PaleoResearch lab, included the following activities: cleaning the mano, extracting analyzable material, purifying the material, staining samples, identifying pollen and starches, and then comparing this data with reference material collected at the Intermountain Herbarium at Utah State University as well as at the University of Colorado Herbarium to help identify and connect the pollen samples with the specific family, genus, and species of particular plants (Cummings 2025).

pXRF

A selection of pictographs at both Site 1 and Site 2 were scanned with a Bruker Tracer 5g handheld X-ray fluorescence spectrometer to identify trace elements present in red, black, and yellow pigments found in pictographs at each individual site. This pXRF machine was operated by Senior Archaeologist Kathy Davis, from Far Western Archaeological Research Group, who was contracted to perform the pXRF analysis for this thesis (Far Western 2025).

Both pXRF scans and digital photographs of sample pictographs were taken. All six star pictographs present at Site 1 were scanned. A total of four pictographs were scanned at Site 2—two stars, one handprint, and one amorphous pictograph. Site 2 sampling proved somewhat more difficult because the majority of pictographs are found at heights well above arm's length.

All of the pictograph scans included a baseline scan of adjacent unpainted base rock for comparison analysis. Analysis consisted of examining the pictographs for the presence or absence of iron, mercury, and manganese in the scans to determine whether pigments were derived from iron oxides, cinnabar, or charcoal (Far Western 2025).

A mudball offering was also scanned at Site 2. These mudball scans were cross-compared with natural mud samples located within the spring found at Site 2. The mud balls are

archaeological features that were thrown onto the ceiling of the cave at Site 2, and they are of great research value and interest in and of themselves.

It must be added that seven more scans were taken of three pictographs found in an overhang located approximately 1/2 mile from Site 2, and forming a piece of the entire cultural complex surrounding Site 2. These scans followed the same procedure outlined above, and they are of interest because the results share similarities with the pictographs found at Site 2 and they highlight the fact that these pictographs are still relevant in the worldview of the cultures that created them.

pXRF analysis and comparison was performed at the Far Western lab following the in-the-field data collection process (Far Western 2025). Subsequently, INFRA-ART, an open-source “digital support tool for heritage research specialists working with spectroscopic techniques,” assisted with an intricate and detailed interpretation of the pXRF data (INFRA-ART 2025). Ioana Cortea, Project Lead, led the effort to cross-compare our pXRF data with data housed in the INFRA-ART digital library; she also helped with a detailed interpretation of the pXRF data, amplifying the results of Far Western’s initial analysis.

Artificial Intelligence

Because AI is on the rise in so many different fields, I wanted to dive into some experimental methods to use it to support understanding star ceiling production and digital reconstruction, thereby opening up new avenues for investigating star ceilings. This set of methods is experimental, of course, but is important, given the various potential novel uses for generative AI in archaeology and rock art studies. The methods contained in this subsection of the thesis are meant to be exploratory and to augment the multi-methods approach employed in researching the star ceilings found at Site 1 and Site 2.

As such, three distinct AI-driven methodologies were utilized: 1) using AI to visually reconstruct rock art to support data interpretation related to star ceiling pictographs; 2) using AI to digitally restore/repair an image of a pictograph; and 3) using AI to create a theoretical star ceiling algorithm model to help conceptually comprehend the star ceiling production process.

Regarding the visual reconstruction technique, digital images of pictographs were uploaded into a standard generative AI application, specifically, Google's Gemini AI Pro. Commands were given to the application to reconstruct the images. The AI-manipulated image was then visually compared with the original image. This is a relatively simple process, but the outcomes are interesting. What's more, and in line with visual reconstruction, digital images were also uploaded into an application created by Michal Lukac, CEO of Ximilar. Ximilar's AI platform and the AI application removed the rock canvas background, allowing the artwork itself to be viewed without the stone canvas, supporting a different and somewhat more detailed look at the actual pictograph.

With respect to the technique of digital restoration and repair, Alex Kashkin, an engineer working at the Massachusetts Institute of Technology, developed an AI-assisted art restoration tool for use with paintings (Chu 2025; Kashkin, personal communication 2025). I wanted to see if it would work with rock art. So, for the purposes of this thesis, I contacted Mr. Kashkin and he used his technique with a digital image of a pictograph found at Site 2. In essence, Alex trains AI to identify areas of visual damage on a painting. The painting is then masked with an ultra-thin AI-generated coloring polymer to restore the image to its original condition. The process is typically used on flat planar surfaces, like actual real-life paintings, that support masking. In this way, a painting is only covered, enabling non-destructive conservation. But in the case of this thesis research, the AI-generated restoration process was completely digital, and the application

attempted to apply a digital AI-generated overlay to fill-in AI-identified damage to the digital image of the pictograph (Kashkin, personal communication 2025).

Finally, in utilizing AI to create a star ceiling production algorithm model, I again employed a common generative AI application. I wanted to determine if there was a way to build an algorithm, or set of algorithms, that could conceptually describe the production of star ceilings. This was a relatively simple process, but to conceive of an AI-generated algorithm could support further comprehension of star ceilings and even expand our notions of rock art. Horn and colleagues (2022) describe the future of AI approaches to rock art studies as depending on the possibilities of theorizing about rock art itself. By seeking to create a rock art production algorithm, as it were, AI can potentially assist the expansion of our conceptual/theorizing capabilities about rock art, its production, and, perhaps in some cases, its use.

Virtual Reality

The VR process of data recording is also experimental and exploratory in this thesis. This set of activities is designed to implement the multi-methods approach while also pushing the boundaries of the site recordation process. My hope is that this technique will help inform digital conservation activity, star ceiling interpretation, data collection, experiential modes of archaeological research, and more. In this case, VR documentation was restricted to Site 2.

With respect to definitions, VR in this context is defined as: An immersive digital experience where a user interacts with a computer-generated artificial 3D rendition of the world through specialized equipment (Merriam-Webster 2024).

Jay Salois, founder of VRtical Media, was contracted to perform the VR rendition of Site 2. Mr. Salois has years of experience in using VR and 3-D technology to document historic properties. For the VR digital recordation and documentation of Site 2, a professional 360°

camera (Insta360 Pro 2) and a drone (DJI's Mini 4 Pro) were both used. The use of a drone to support VR documentation was approved by the BLM (Merritt, personal communication 2025). The site was recorded as a series of 360° panoramas captured to simulate a walk-through (called a "wayfinding") experience within the cave. Each panorama was captured at a minimum distance of 1.5 meters from the cave walls. The 360° camera used six 200° lenses to capture the full environment. In this way, the VR experience is rooted in a type of photogrammetry site-capture procedure that forms the basis of the VR environment.

Camera settings for this VR data-collection activity included the following:

1. Isolated exposure: Each lens performed exposure independently rather than applying a single exposure across all six lenses, thereby preserving more detail.
2. HDR bracketing: Multiple exposures per lens were captured to increase dynamic range; combined with isolated exposure, this improves image quality in post-production.
3. Remote trigger: Panoramas were triggered via a mobile app to enable us to be placed outside the capture area, so we wouldn't appear in the imagery.
4. 3D stereoscopic: When viewed in a VR headset, this type of stereoscopic capture improves depth perception and photo realism.

A secure webpage was then set up allowing access to the 3D and VR renditions of Site 2. This webpage will be supported in perpetuity. Because there are strictures about publishing images from Site 2, per the ARPA permit, the secure webpage will be configured to provide access only to BLM Cultural Resource staff, University of Maryland Thesis Committee members, and if possible, to the Navajo THPO as well. On top of this, VR headsets were provided to the BLM Rio Puerco Field Office and the Navajo THPO, as appropriate, for

permanent use. University of Maryland Thesis Committee members were provided VR headsets on a temporary basis for the purposes of this thesis.

Consultation with Conservators

To ensure the long-term integrity of these special sites, especially with the increasing threat of environmental changes, etc., I consulted with professional conservators to attempt to translate my collected data—especially the pXRF data—into a theoretical preventive conservation plan. This approach helped to move my thesis research beyond documentation and experimental approaches, to actually using the data to theoretically prescribe non-destructive preservation interventions. (By the way, this process proved difficult because conservators are hard to pin down for consultation!)

Broadly speaking, conservation may be considered the proactive action to stabilize and repair objects, while preservation is the non-invasive approach to minimizing and preventing damage to a site or an object like rock art (Museum of Ontario Archaeology 2026). Rock art sites are highly complex sites with multiple sources of potential damage, including natural weathering, vandalism, development, and more (Laue and Dean 2022). Conservation and preservation approaches, therefore, have to take into account a myriad of complex dynamics in the effort to create a viable conservation, preservation, and/or preventive conservation plan. Because of the limitations of my own experience with conservation science, much of the work in this section is related to preservation, though the AI and VR portions of this project can be harnessed for digital conservation and digital preservation activities.

For this portion of the thesis, I consulted with longtime conservator Victoria Clow, a highly regarded conservator and professor who has spent decades working with the General Services Administration throughout the Southwest and is currently serving as a Senior Scientist

with Terracon. Not only is Professor Clow expert in conservation and preservation, she also serves on the Executive Board Committee of Preservation Dallas, an organization dedicated to protecting the history and culture of Dallas. In my discussion with Professor Clow, we created a theoretical preventive conservation plan, centered on passive interventions, that could be applied to the artworks found at Site 1 and Site 2.

Chapter 5: Results

As a reminder, this thesis aims to expand existing star ceiling research through data collection performed at two distinct star ceiling sites—one found on private land and the other on Bureau of Land Management (BLM) public land—both located within the traditional Navajo landscape, the *Dinétaah*. The results offered here present my initial findings from the various techniques used to investigate these two star ceiling sites. The results are of real interest, and they highlight the effectiveness of a multi-methods research design.

This chapter describes results from two types of investigation: (1) traditional archaeological methods—field data and use of pXRF—and (2) more experimental methods—the use of Artificial Intelligence and Virtual Reality.

Field Data and pXRF Results

The field data collected offers insights related to the archaeological contexts of each site, whereas strategic use of pXRF reveals the chemical constituents of the analyzed pictographs.

Fieldnotes and Sketches Results

Fieldnotes and sketches were made at Site 1 and Site 2. Fieldnotes include measurements and pictographic orientation, as well as compass orientation, elevation, and other data. Measurements were also made of each pXRF-analyzed pictograph and hand-recorded in a fieldnote booklet. Together with this, each analyzed pictograph was recorded in sketch format. Site 1 and Site 2 were also both sketched, and so were some of the other artistic and cultural resource material found at Site 1 in particular.

Analysis of the fieldnotes and sketches produced several important results. A total of 20 sketches were made for both sites, with 14 made of Site 1 (nine of Alcove 1, four of Alcove 2,

and one sketch of both alcoves together) and six made of Site 2. Though a single datum point was not utilized because of the nature of the sites and the objects of study, such as pictographic rock art, the pictographs and other features of each site are shown in orientation to the ground and the ceiling, other artworks and distinctive rock features, or both, and to GPS coordinates. As an aside, more time was spent documenting Site 1 because there is no New Mexico State Archaeological Record for this site, whereas Site 2 already has a New Mexico State Archaeological Site number and has been extensively documented in the past (Christian 2012; NMCRIS 2025; Appendix 1).

The fieldnotes and sketches also record site measurements, site orientation, and site elevations. Site 1, Alcove 1 measures approximately 130 feet wide at its mouth, and 8.5 feet tall at its apex; Alcove 2 measures 20 feet wide at its mouth and 32 inches in height at its apex. Site 2 is roughly 100 feet wide and 60 feet tall at its apex. Both alcoves at Site 1 face south, meaning that an observer standing within these alcoves and looking out of them is looking due south, while if they are looking into the interior of each alcove they are looking due north. The same is true for Site 2. Each site sits at an elevation of roughly 6,500+ feet above sea level.

Further analysis of the sketches reveals that the pictographic stars are often very close to being equilateral in size—especially at Site 1—a pattern that becomes evident when the drawings and measurements for each star are compared to each other (Table 1). My sketches highlight this tendency across both star ceiling sites. The strictly star-shaped pictographs on view at Site 1 and Site 2 average 3.8 by 3.15 inches in size; when the measurements for the two largest stars are removed, the average for the remaining six smaller stars is equal to 3.16 by 3.4 inches. This tendency toward equilateral-ness may suggest a type of iconographic uniformity/stability in

how these pictographic stars were conceived of and produced. I think this is an important detail and it will be discussed more fully in the Analysis chapter.

Table 1: Star Size and Handprint and Amorphous Pictograph Measurements
Based on Sketch Measurements

Star	Size in inches
Site 1, Star 1	3" x 4"
Site 1, Star 2	4" x 4"
Site 1, Star 3	3.25" x 4.25"
Site 1, Star 4	4.25" x 4.25"
Site 1, Star 5	2.75" x 2"
Site 1, Star 6	6" x 6"
Site 2, Star 1	1.75" x 2"
Site 2, Star 2	5.75" x 3"
Site 2, Handprint	6" tall x 5" wide
Site 2, Amorphous	1.75" approximately

The sketches also emphasize the significance of star pictograph placement. At Site 1, Alcove 2, the stars are painted remarkably close to the ground—between 18 and 28 inches above the alcove floor (Figure 9). This is a very small space indeed, and it points to the fact that the artist must have been lying on their back in order to create/paint these stars. In point of fact, comparisons between the two sites show a striking contrast in the heights at which stars were produced. At Site 1, the pictographs range from 18 to 31 inches above the ground, while at Site 2, the stars appear more than 50 feet overhead. This disparity points to very different physical and perhaps functional contexts of each site. The sketches from Site 1, Alcove 2 also document the close proximity of what appears to be a bentonite clay quarry situated only inches from the pictographs, a detail that may point to clues about the site's use or meaning (Figure 10). Also, the arrangement of the stars in this alcove hints at a possible constellation pattern that

could correspond to an important Navajo constellation. (See fieldnotes in Appendix 3 for amplification.)

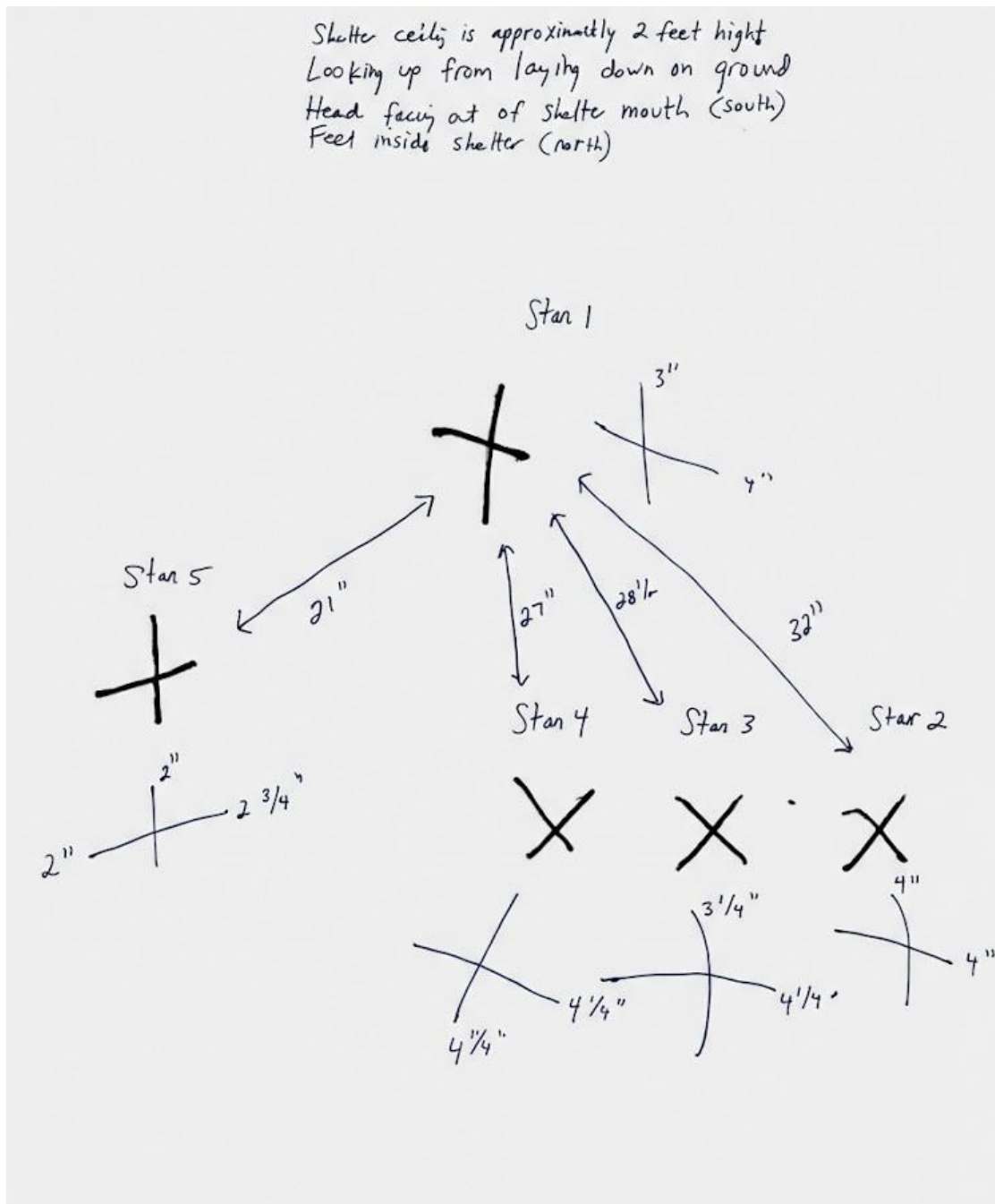


Figure 9: Site 1, Alcove 2, Stars 1-5, in a potential constellatory pattern.
Digitized rough sketch made by author.

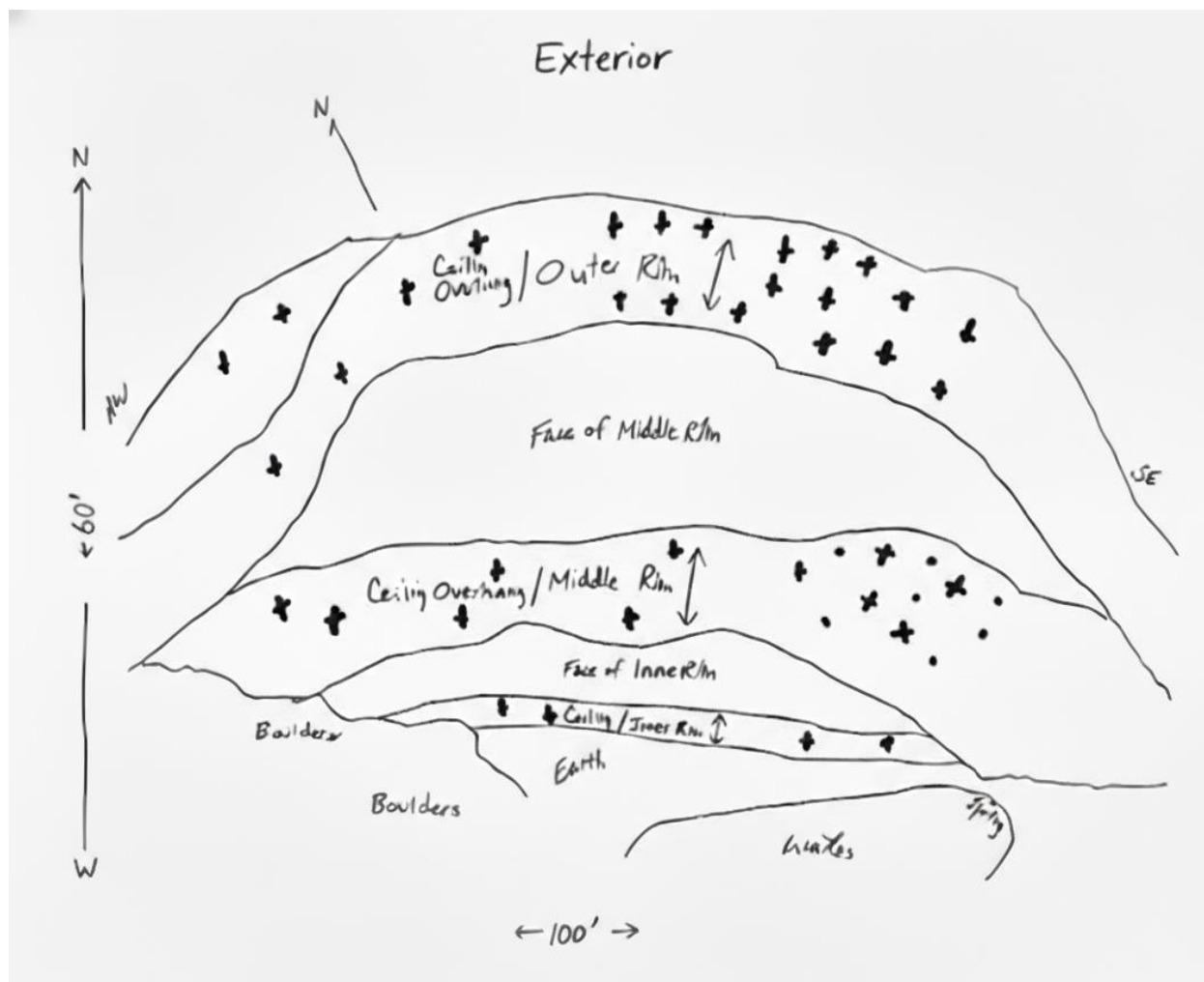


Figure 10: Rough sketch of locations of stars and mudballs at Site 2. Crosses indicate stars and dots indicate mudballs. Digitized sketch made by author.

Field Photography Results

Digital photographs were taken of each respective site and alcove using both a Fuji Film Finepix digital camera and a Canon EOS digital camera. These helped me to document and exhibit each site and the visual context of the artworks themselves. In addition, each individual pictograph that was analyzed utilizing the pXRF machine was photographed to support data analysis and interpretation. This procedure also helped me to catalogue the analyzed pictographs.

A total of 81 photographs were taken by the author, and 13 were taken by Kathy Davis, Senior Archaeologist and pXRF technician. As with the field sketches, the largest majority of photographs obtained by the author were taken at Site 1, 69 in total. Twelve photographs were taken by the author at Site 2. Seven photographs were taken with an Infrared lens to experiment with how light refracts off of the pictographs. These were mostly taken at Site 2. The Infrared lens did not enable the pictographs to show up differently than the normal lens.

More photographic effort was made at Site 1. Again, since the site is undocumented, it warranted more photography. Also, even though Site 2 contains close to 200 pictographs, these are mostly positioned beyond arms-length and could not be analyzed with the pXRF machine (disappointingly), so more focus was paid to the pictographs on display at Site 1, since they were all able to be examined with the pXRF device.

Aside from maintaining a digital record of the sites and the pictographs, the digital field photography supports visual analysis of the pictographs as well and helps us see the pictographs with greater attention to detail (Collier and Collier 1987). For instance, the photograph of Site 2, Star 1, upon close inspection and after the conclusion of fieldwork, supports the hypothesis that this pictograph may have been painted with a finger, as opposed to some other painting method (Figure 11). Since some of the pictographs featured at Site 2 may have been painted with stencils and stamps (Christian 2012:98; Jett 1984:25-40), this potential finger-painting method is of interest and could support future research. Further photographic analysis could also help to determine which side of the star was painted first, etc. Since the bottom and left of the star exhibit more pigment, it may be possible to state at this point that the bottom and left sides of this pictograph were painted first, meaning the pigment was smeared from the bottom up and from the left to the right.



Figure 11: Site 2, Star 1 may have been painted with the artist's finger.
Photo taken by author.

The Results of Other Archaeological Features and Artifacts

The fieldnotes and field sketches, together with my digital photographs, reveal other archaeological features beyond the pictographs themselves. For instance, at Site 1, Alcove 1, 30 petroglyphs are identified, 28 of which are distributed across two panels located near the single black star pictograph; most of these petroglyphs are located at ground level. Two additional petroglyphs are carved directly onto the alcove floor itself (Figure 12). All of these petroglyphs are in the style that Schaafsma calls “Type I and Type II” Pueblo petroglyphs (her designations for this style), described by her as typically representing “broad-shouldered men” averaging one

to three feet in height (1963:26, 28). These, according to Schaafsma, predate the star pictographs documented in this thesis (1963:37), and they are related to what Schaafsma says is the Basketmaker III to Pueblo I time periods, roughly 700-900 AD (1963:31); therefore, these petroglyphs belong to the Ancestral Pueblo cultural tradition.

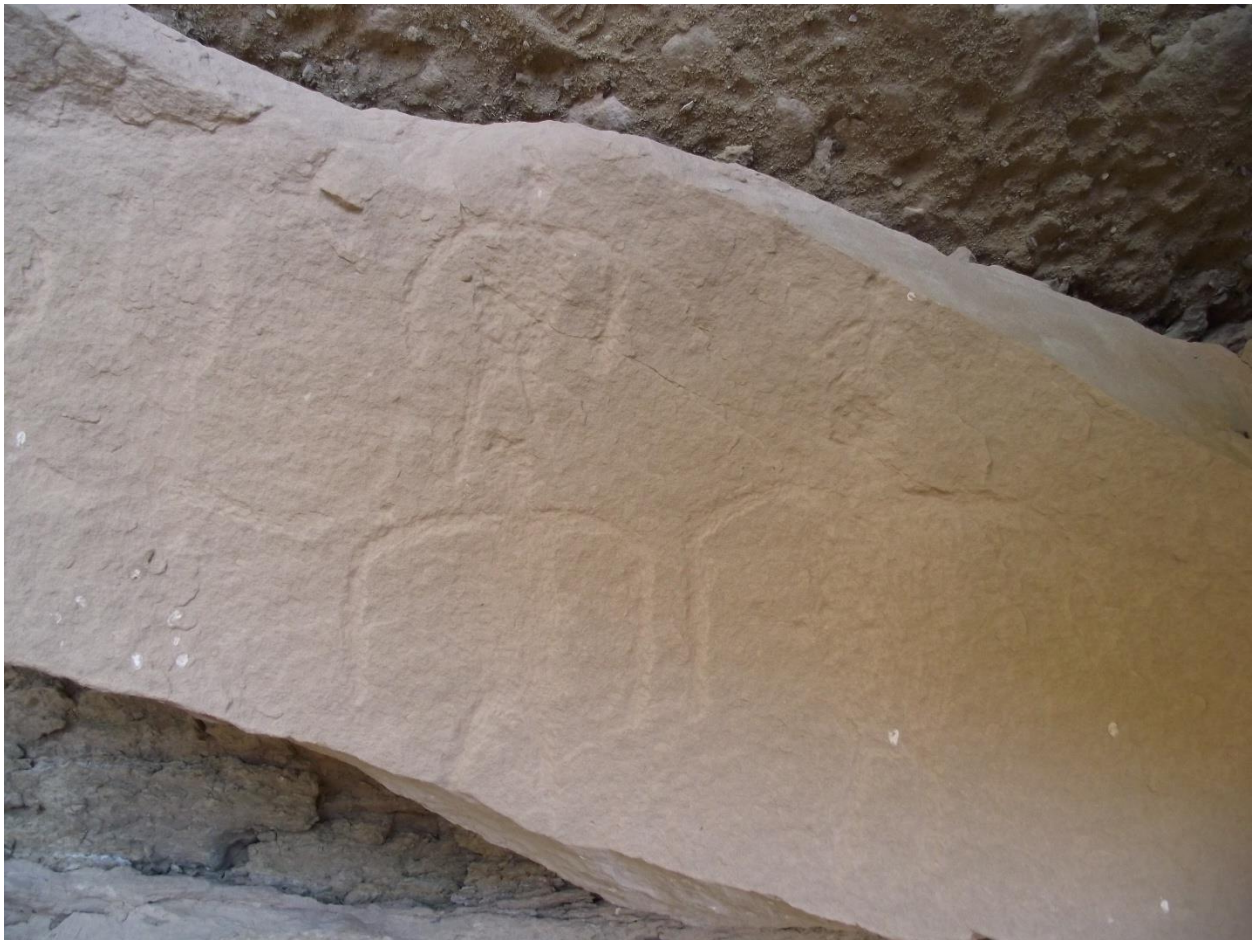


Figure 12: Site 1, Alcove 1, Petroglyphs of “broad-shouldered men” as described by Schaafsma (1963:26,28). Photo taken by author.

The sketches also record evidence of a hearth in Site 1, Alcove 1, including burnt wood, charcoal, and several grinding stones. Site 1, Alcove 2 contains what looks to be a bentonite clay quarry as well, which is interior to the overhang where the five star pictographs that show a potential constellation pattern are on display (Figure 13).

Too, there is evidence of site change at Site 2 since the last time I researched the site in 2012. The archaeological material found on the floor of the site—corn cobs, pottery, sheep bones, and more—are no longer present. I suspected that the BLM performed a Phase I or II since 2012; however, according to Michael Merritt, the BLM Archaeologist in charge of Site 2, this change is from natural processes (personal communication 2026).



Figure 13: Site 1, Alcove 2, Bentonite clay vein. Photo taken by author.

Petroglyphs are also found on boulders on the floor of Site 2, including arrow-shaped carvings that I previously speculated may have served as arrow-straighteners (Christian 2012:87). Additional features at Site 2 include a historic homestead site at the cave mouth and associated sheep fencing and enclosures (NMCRIS 2025; Appendix 1). The site also contains

hundreds of mud balls, most of them thrown onto the southeastern sections of the cave ceiling. What is more, adjacent to Site 2, located on a rock face approximately 1/2 mile west of Site 2, are several other petroglyphs and pictographs, including coiled serpents, various animal figures, and painted images of the sun and moon (Figure 14).



Figure 14: Example of petroglyphs adjacent to Site 2. Photo taken by author.

Pollen Analysis Results of a Mano from Site 1

As described already, Site 1, Alcove 1 contains one black pictograph star. Situated on the floor of the alcove immediately adjacent to this single star pictograph sit several manos, or grinding stones; these are associated with the hearth that is also present here. One grinding stone was selected for pollen analysis to determine if the stones were used to process plant matter, and

if so, to identify which plants were processed. The pollen analysis from the mano that was sampled from Site 1—and subsequently returned to the site—yields some very interesting results. Dr. Cummings’s report is quoted here with the findings from the PaleoResearch Institute lab:

The pollen signature from the mano yielded a very limited record including *Juniperus*, *Pinus*, and *Quercus* pollen representing juniper, pinion pine, and oak trees growing near the shelter. Recovery of small to moderately small quantities of *Amaranthaceae*, *Artemisia*, Low-spine *Asteraceae*, High-spine *Asteraceae*, and a larger frequency of *Poaceae* pollen represent local plants including members of the goosefoot family, sagebrush, ragweed and similar plants, other members of the sunflower family, and grasses. This pollen record suggests grinding grass seeds using this mano. A scan of the microscope slide revealed no *Zea mays* pollen and no starch. (2025:2-4; Table 2)

Table 2: Pollen Types Found on Mano (Cummings 2025:4)

Scientific Name	Common Name
Arboreal Pollen (Tree Pollen):	
<i>Juniperus</i>	Juniper
<i>Pinus</i>	Pine
<i>Quercos</i>	Oak
Non-Arboreal Pollen (Non-Tree Pollen):	
<i>Amaranthaceae</i>	Amaranth Family
<i>Asteraceae</i>	Daisy/Sunflower Family
<i>Artemisia</i>	Sagebrush
Low-Spine <i>Artemisia</i>	Includes ragweed, cocklebur, sumpweed
High-Spine <i>Artemisia</i>	Includes aster, rabbitbrush, snakeweed, and sunflower
<i>Poaceae</i>	Grass Family

According to Cummings, no *Zea mays* (corn) pollen is found on the mano, highlighting the fact that at this site, at some point in time, activities related to the grinding of non-arboreal plant matter, including grassy plants and seeds, sagebrush, amaranth, sunflower, and differing types of artemisias took place. The landscape surrounding the site is populated by wild oaks, Juniper, and Pinyon trees, as well as the other species witnessed in the pollen analysis results. Interestingly, the landscape is not conducive to farming, and I wonder if this is the reason corn is not represented in the pollen sample.

There is the opportunity to perform a radiocarbon analysis of the charcoal present in the hearth found near the mano, and spatially associated with the mano, but there is not adequate funding to complete this radiocarbon project at the present time. Without this radiocarbon dating technique, it is difficult to definitively date this mano. Notwithstanding, one-handed manos—

which this sampled mano is representative of—have been in use in the Four Corners region since Archaic times and well into the Basketmaker and Pueblo time periods (Crow Canyon Archaeological Center 2014, 2025). They are associated with basin style metates, and at Site 1, the alcove floor itself serves as the basin metate where there is evidence of grinding (Figure 15). (See Appendix 4 for the full mano report.)



Figure 15: Manos found inside Site 1, Alcove 1. Footprints not the author's.
Photo taken by author.

Portable X-Ray Fluorescence Results

For the pXRF results, I rely heavily on Far Western's Analysis report (Far Western 2025). This report is very detailed and provides the raw data results, together with discussion, for the entire pXRF data collection process. To repeat, at Site 1, six star pictographs were scanned

with the pXRF machine and a total of four pictographs were scanned at Site 2: two stars, one handprint, and one amorphous pictograph. A mudball offering was also scanned at Site 2; this mudball scan was cross-compared with a scan of natural mud samples located within the spring found at Site 2. Together with this, seven more scans were taken of pictographs found in an alcove adjacent to Site 2, situated about 1/2 mile to the west from Site 2. A detailed description of the machine used and the exact methodology performed is found in the Far Western report. (See Appendix 5 for the full report.)

The initial results of the pXRF scans reveal that, as shown in Table 3, there is an abundance of iron in all of these scanned pigments, suggesting that the pigments were produced from hematite for red pigments and magnetite for black pigments (Far Western 2025:1). Far Western highlights two exceptions to this: 1) the black pigment from the sun pictograph located in the alcove adjacent to Site 2 shows evidence of lead, and 2) the black amorphous pictograph from Site 2 exhibits an increased level of manganese.

Ioana Cortea, Project Lead at INFRA-ART, an open-source “digital support tool for heritage research specialists working with spectroscopic techniques” (INFRA-ART 2025), also provided data interpretation and analysis for the pXRF data obtained by Far Western. The initial results and analysis of the pXRF data from Cortea’s perspective highlight the following, and I paraphrase Cortea here:

In general, the bedrock found at both sites is calcium-rich, and some of the calcium detected in the pigmented areas clearly derives from the rock substrate. However, several samples show calcium levels significantly higher than the bedrock average, indicating an additional calcium source within the pigments themselves (Cortea 2025:2). Strontium follows a similar pattern witnessed with these findings for calcium. Because strontium commonly occurs

as an impurity in calcium minerals, its strong correlation with calcium across the dataset is expected; however, several pigmented areas—particularly several of the black-pigmented areas—display elevated strontium values that reflect contributions from specific pigments in addition to the strontium originating from the bedrock (Cortea 2025:2). (See Appendix 6 for the INFRA-ART analysis.)

Table 3: Elements Identified in Analyzed Pigments, as Reported by Far Western

Pictograph Number	Pigment Color	Elements Identified
Site 1, Star 1	Black	Iron
Site 1, Star 2	Black	Iron
Site 1, Star 3	Black	Iron
Site 1, Star 4	Black	Iron
Site 1, Star 5	Black	Iron
Site 1, Star 6	Black	Iron
Site 2, Star 1	Red	Iron
Site 2, Star 2	Red	Iron
Site 2, Amorphous	Black	Manganese
Site 2, Handprint	Orange	Iron
Site 2, Mud Offering	Gray Mud	Identical to Spring Mud
Adjacent to Site 2, Sun	Center of Sun, Red	Iron
Adjacent to Site 2, Sun	Right Edge of Sun, Black	Lead
Adjacent to Site 2, Sun	Top of Sun Ray, Red	Iron
Adjacent to Site 2, Sun	Left Edge of Sun, Black	Iron
Adjacent to Site 2	Center of Moon, Red	Iron
Adjacent to Site 2	Bear, Black	No increase over bedrock
Adjacent to Site 2	Chicken, Black	No increase over bedrock

Site 2, Star 2 exhibits the highest iron concentrations, clearly linked with the presence of red iron oxides like hematite (Corteza 2025:2). This same pictograph also contains the highest concentrations of chlorine, chromium, and niobium—elements that may serve as potential “provenance trace markers” (Corteza 2025:2). The solar pictograph adjacent to Site 2, in the scan of the top solar ray, shows the highest mercury value, another element that may function as a “useful trace marker” (Corteza 2025:2). Bromine can also be used as a potential “fingerprint” to determine geological source and geological origins, with the highest bromine values occurring in Site 2, Star 1 (Corteza 2025:2).

The dataset related to black pigments indicates the use of multiple black pigment types, including manganese-based materials, galena, and bone black (Corteza 2025:3). The amorphous black pictograph at Site 2 is manganese-rich black earth, the main coloring components based on iron oxides and manganese oxides (Corteza 2025:3). The chicken and bear pictographs located in the alcove near Site 2 and adjacent to the solar pictograph, about 1/2 mile to the west, show the highest peak of calcium when compared to the whole dataset, likely reflecting the use of calcium phosphate and calcium carbonate (Corteza 2025:3). Curiously, the bear pictograph also contains the highest strontium levels, which is “linked to its incorporation into the bone mineral hydroxyapatite due to its chemical similarity to calcium” (Corteza 2025:3).

Site 1, Stars 2 and 3 exhibit the highest arsenic peak values. In bone black pigments, arsenic is typically associated with the dietary intake of animals, as arsenic can accumulate in bone tissue over time (Corteza 2025:3). For Site 1, Star 6, “The overall chemical fingerprint, when compared with the other black-pigmented areas, suggests the use of a different black earth possible applied over an original degraded bone black pigment” (Corteza 2025:3).

Cortea's results and interpretations of the pXRF data are extremely detailed and in-depth, and they highlight the potential to obtain relevant information apropos of rock art pigments via XRF data-collection methods. The disparity between the level of interpretations provided by Cortea vis-à-vis Far Western is explained by the fact that INFRA-ART is a worldwide spectral data library. Cortea has access to an XRF data repository that is incredibly rich, and she therefore can offer more detailed interpretative insights.

Taken together, these results really do accentuate the idea that the pigments used across these two star ceiling sites are varied and not accidental; that is, pigment choice is intentional. The Analysis chapter will dive into this more fully. Suffice it to say, the artists were using pigments from various material sources, and, in some cases, reworking pigments at certain pictographs.

Figures 16–31 show digital images of each pXRF-scanned artwork.

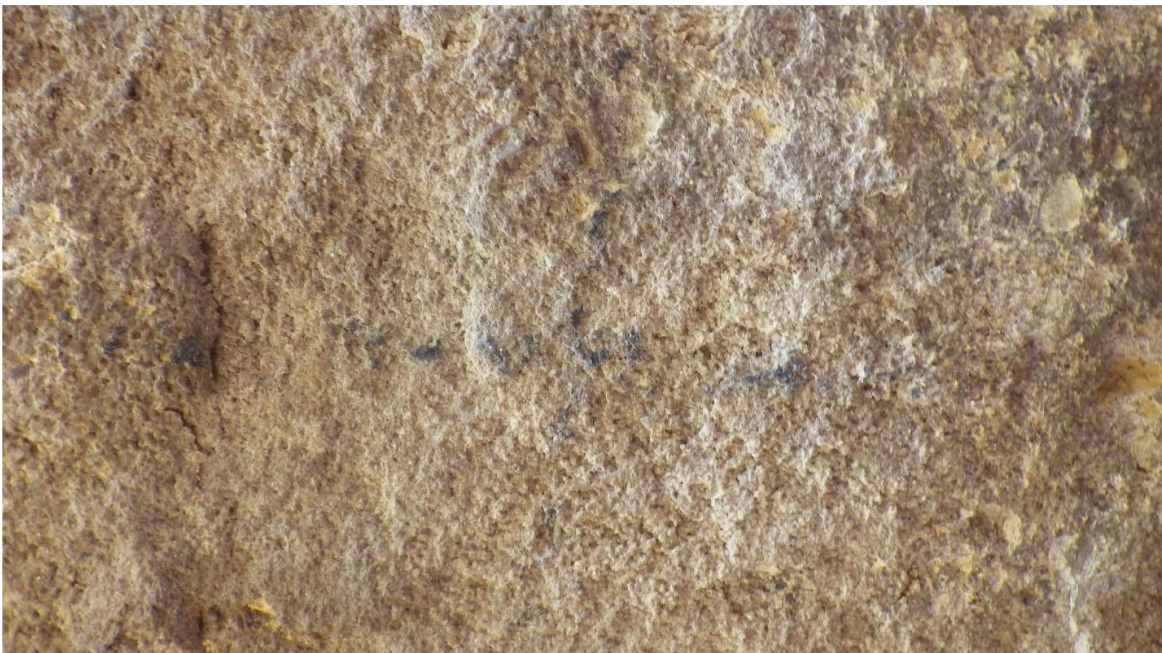


Figure 16: Site 1, Star 1, found in Alcove 2. Photo taken by author.



Figure 17: Site 1, Star 2, found in Alcove 2. Photo taken by author.

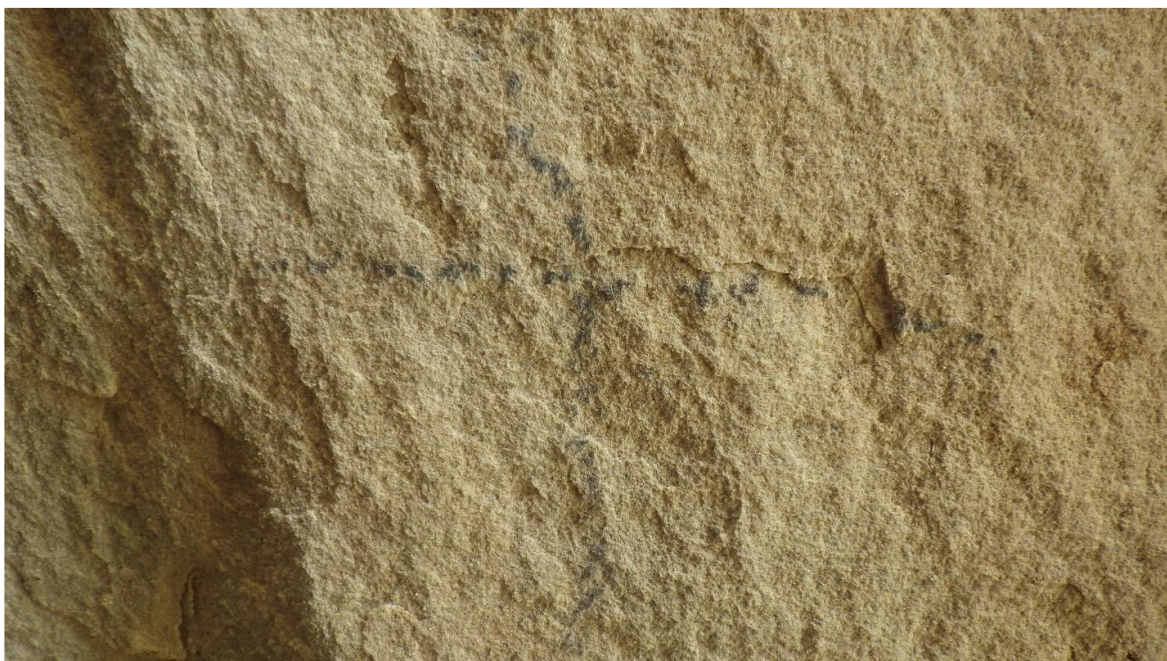


Figure 18: Site 1, Star 3, found in Alcove 2. Photo taken by author.



Figure 19: Site 1, Star 4, found in Alcove 2. Photo taken by author.

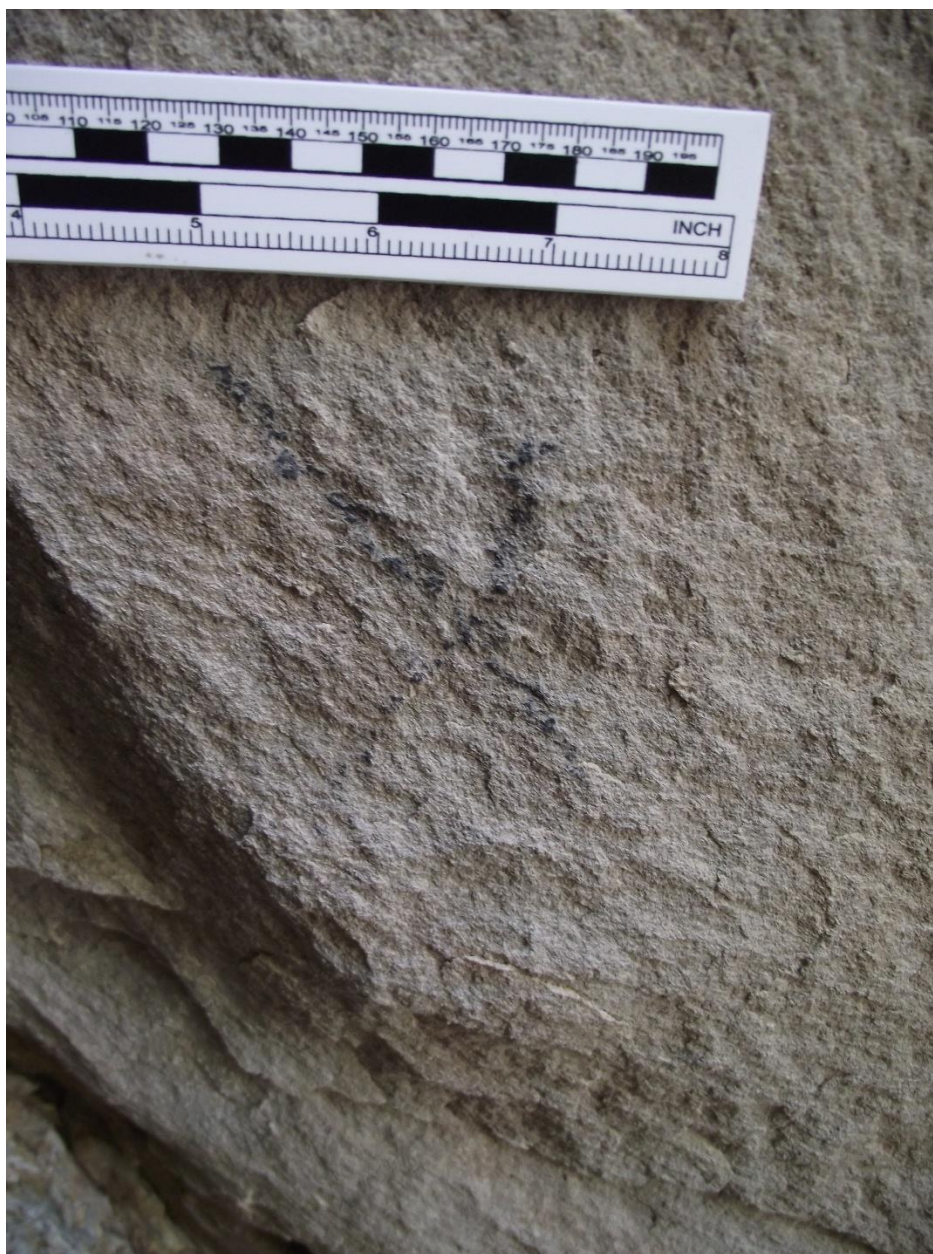


Figure 20: Site 1, Star 5. Photo taken by author.

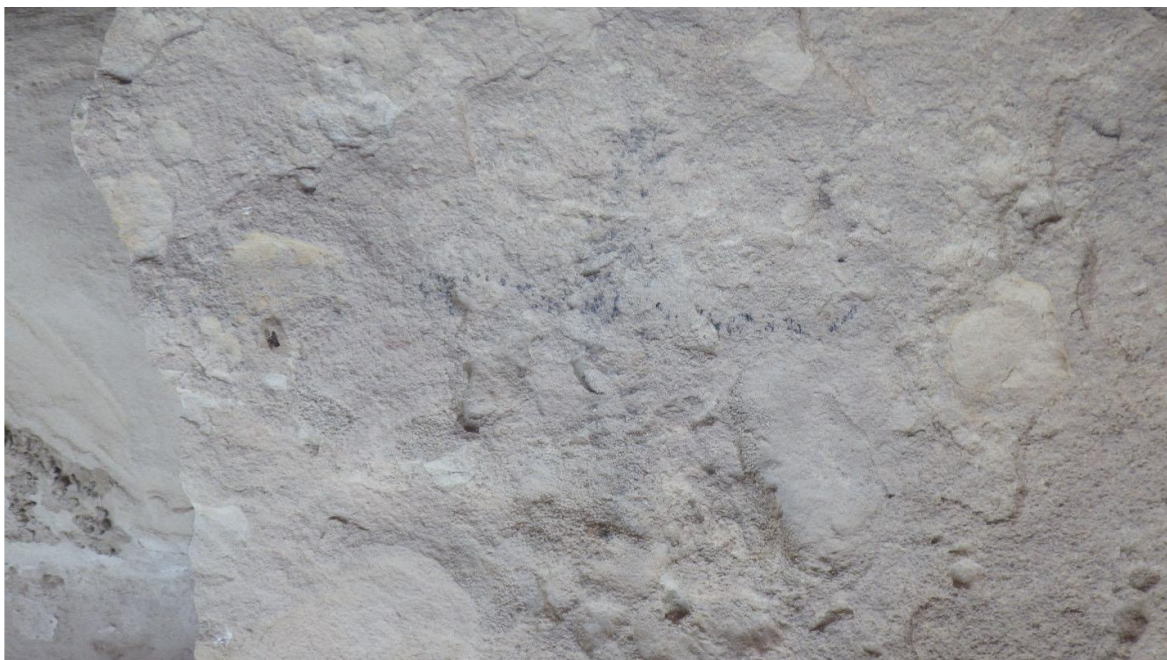


Figure 21: Site 1, Star 6, found in Alcove 1. Photo taken by author.

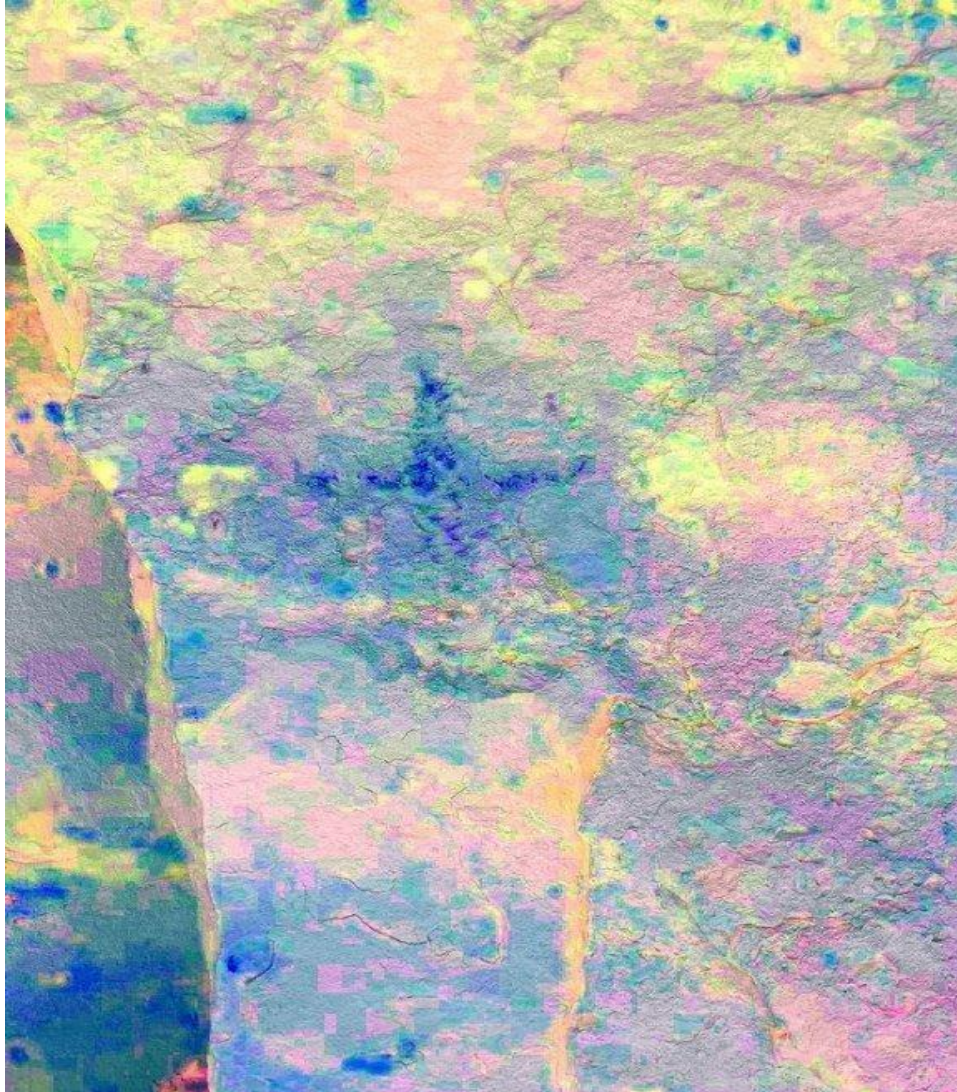


Figure 22: Site 1, Star 6, found in Alcove 1, as modified by Stephen Townley Bassett, Experimental Archaeologist and Rock Art Expert. Photo taken by author.

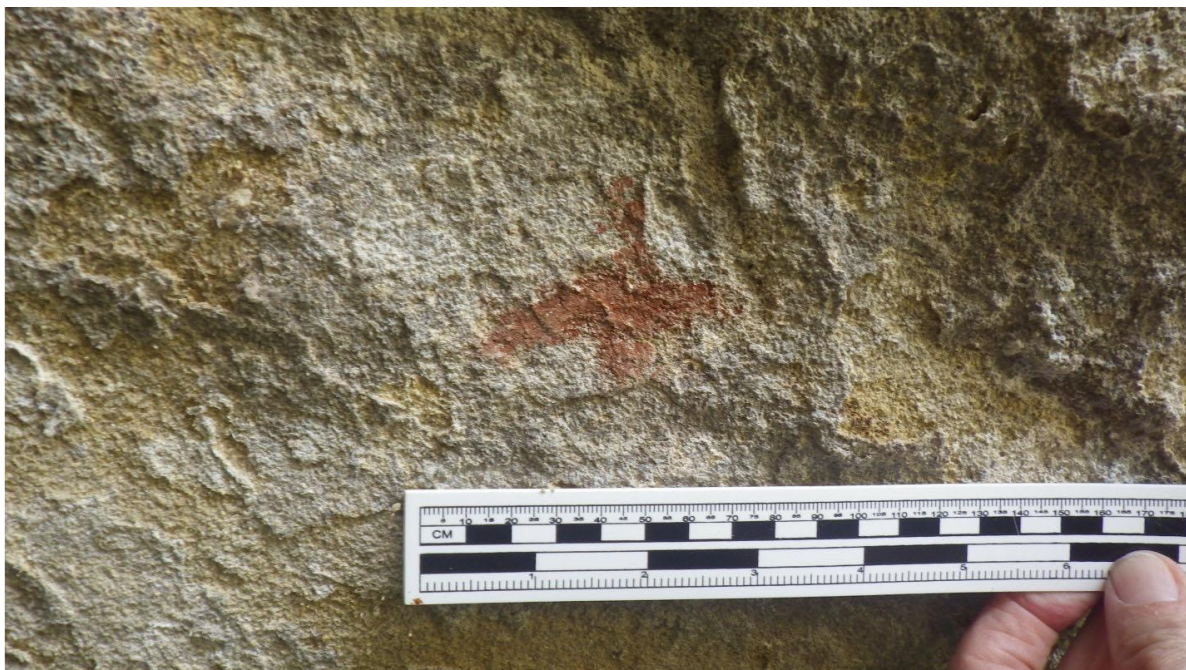


Figure 23: Site 2, Star 1. Photo taken by Kathy Davis, pXRF technician, for the purposes of this thesis and used with her permission.



Figure 24: Site 2, Star 2. Photo taken by Kathy Davis, pXRF technician, for the purposes of this thesis and used with her permission.



Figure 25: Site 2, amorphous black. Photo taken by Kathy Davis, pXRF technician, for the purposes of this thesis and used with her permission.



Figure 26: Site 2, handprints. Photo taken by author.



Figure 27: Site 2, mudball examples. Photo taken by author.



Figure 28: Adjacent to Site 2, Sun and Moon (Sun right with red rays and black pigment inside).
Photo taken by author.



Figure 29: Adjacent to Site 2, Sun and Moon (Sun right with red rays and black pigment inside). Photo of author taken by Kathy Davis, pXRF technician, for the purposes of this thesis and used with her permission.



Figure 30: Adjacent to Site 2, Bear. Photo taken by author.

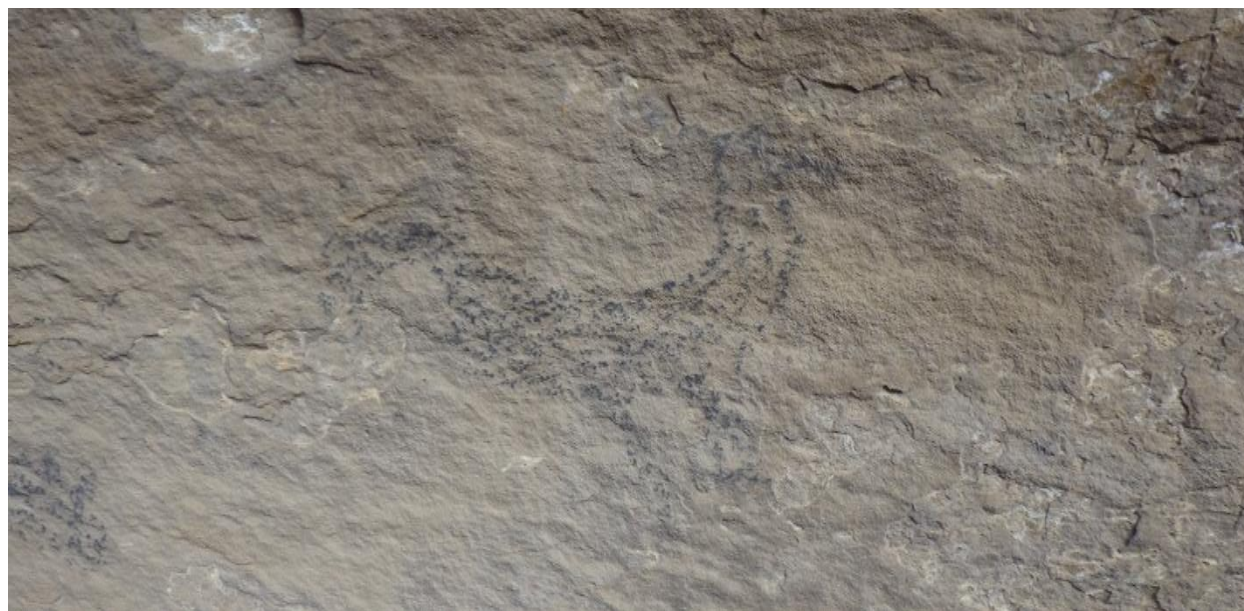


Figure 31: Adjacent to Site 2, Chicken. Photo taken by author.

Emerging Technologies: Artificial Intelligence and Virtual Reality

The results from the experimental work with emerging technologies, specifically AI and VR, are presented in this section, offering insight into these tools and how they enable digital research, digital reconstruction, digital restoration, education, and digital preservation. These techniques and technologies demonstrate real potential in star ceiling research in particular and rock art research in general, though they also underscore the importance of creating and working from an ethical framework that considers the use of these techniques with culturally significant artworks.

Results of Experimentation with Artificial Intelligence

Several techniques were used to investigate the relevance of using AI to support rock art and star ceiling pictograph examination. These techniques include using AI to reconstruct star ceiling pictographs, restore star ceiling pictographs, and support the creation of an algorithm to help conceptualize star ceiling production.

AI reconstruction with digital paint: Regarding the visual reconstruction technique, digital photographic images of pictographs were uploaded into a standard generative AI application, Gemini Pro, leaving out all of the site's details, including the site's location and any other description of the site itself. I asked AI to reconstruct the images to appear as if the images were painted now. The results are interesting and may have potential for future studies in rock art.

The first image uploaded into AI for digital reconstruction is from Site 2; it contains two pictographs and the remnants of multiple mud ball offerings (Figure 32).



Figure 32: Photo of pictographs from Site 2 without AI reconstruction. Photo taken by author.

AI provided a reconstruction per the command, “please reconstruct this image to make the original image look as if it were painted now” (Figure 33).



Figure 33: Digital image of the AI-reconstructed pictographs (AI-generated restoration by Gemini Pro 9/1/2025).

The second digital photographic image uploaded into AI for reconstruction is also from Site 2 (Figure 34).



Figure 34: Photo of pictograph from Site 2 without AI reconstruction. Photo taken by author.

Again, AI provided a reconstruction per the command, “please reconstruct this image to make the original image look as if it were painted now” (Figure 35).



Figure 35: Digital image of the AI-reconstructed Site 2 pictograph (AI-generated restoration by Gemini Pro 9/1/2025).

The results of these reconstructions speak for themselves. They accentuate the artworks in such a way as to highlight details that may go unnoticed without the reconstruction technique being used. This perspective can ultimately help researchers to better see patterns in the design, even noticing patterns that were invisible before the digital reconstruction.

The following examples are reconstructions based on digital images refined by AI to remove the background of the pictographic image. These digital images of pictographs were uploaded into Ximilar's AI platform and the AI application removed the rock canvas background, allowing the artwork itself to be viewed without the stone canvas, supporting a different and somewhat more detailed look at the actual pictographs themselves. Again, all of the site's details, including the site's location and any other descriptions of the site itself were left out of the image upload.

Figure 36 shows a photo of a pictograph from Site 2 without digital manipulation, and Figure 37 shows the same pictograph without the rock canvas background.



Figure 36: Photo of pictograph from Site 2 without digital manipulation. Photo taken by author.



Figure 37: Digital image of pictograph from Site 2 with background digitally removed by Ximilar.

Figure 38 shows a photo of another pictograph from Site 2 without digital manipulation, and Figure 39 shows the same pictograph without the rock canvas background.



Figure 38: Pictograph from Site 2 without digital manipulation. Photo taken by author.



Figure 39: Digital image of pictograph from Site 2 with background digitally removed Ximilar.

These images with the rock canvas background removed highlight certain interesting features of the pictographs, including the center “hole” and center “indent” witnessed in Figures 37 and 39.

Restoring a pictograph with AI: I consulted with Alex Kashkin, an MIT Engineer who trained an AI model to help restore real-life 3D paintings. We experimented with Mr. Kashkin’s AI restoration model with a rock art image from Site 2. Mr. Kashkin fed a digital image of the above pictograph into his AI restoration program. In this case, the AI-generated restoration process was completely digital, and the application attempted to apply a digitally rendered, AI-

generated overlay to fill-in AI-identified damage to the digital image of the pictograph. The results are of value for paving the way for more experimentation with this technique, but not necessarily successful for digital restoration at the present moment.

Figure 40 shows the original image of a pictograph from Site 2 that was fed into Mr. Kashkin's model.



Figure 40: Photo of pictograph from Site 2 without digital restoration. Photo taken by author.

Figure 41 shows the AI-identified areas that need repair and restoration; Mr. Kashkin's model automatically filled in color—what he calls the digital overlay—to be applied to the image.



Figure 41: AI-generated image of areas needing in-filling via Kashkin's method.

Figure 42 shows the final image containing the original photographic image together with Mr. Kashkin's AI-produced overlay.



Figure 42: Digital image of AI-produced digital restoration via Kashkin's method.

In utilizing AI to create a star ceiling production algorithm model, I again employed a common generative AI application, Google's Gemini AI Pro. This was done to determine if there was a way to build an algorithm, or set of algorithms, that could conceptually describe the

production of star ceilings, thus allowing researchers to think more broadly about how rock art is produced. This was a relatively simple process, but to conceive of an AI-generated algorithm could support further comprehension of star ceilings and even expand our notions of rock art. That is to say, we can harness the power of AI to support the way we approach thinking about the artworks themselves, expanding our theorizing capability, in the way that Horn and colleagues (2022) describe it.

The AI command included the following request: “Please generate an algorithm that includes the known variables with the unknown variables of Navajo Star Ceiling production. Known variables include the star representations, the evidence of pigments, the artworks found at heights of 50 feet or more, the cave ceiling itself; the unknown variables include the make-up of the pigments and the method for artistic production, though they could have been produced using stamps applied to long poles or to arrows.”

AI’s response:

“Navajo Star Ceiling Production Algorithm

The following algorithm outlines the steps and variables involved in hypothesizing the artistic production process:

1. Known Input Variables (V K)

These are the established characteristics of the star ceilings:

C loc (Cave Location): Natural rock shelter with an overhanging ceiling.

C hgt (Ceiling Height): Vertical distance from the ground to the art's location (often ≥ 50 feet).

P col (Pigment Colors): Observed colors (predominantly black, red, white; sometimes orange, yellow, green).

A form (Art Form): Star clusters depicted as equal-armed crosses.

A meth (Application Evidence): Physical evidence suggesting repetitive stamping or painting.

2. Unknown Variables (V U)

These are the elements of the process that require further analysis or hypothesis:

P comp (Pigment Composition): Exact mineral or organic source, preparation, and binder of the pigments (e.g., mineral-based ochres, carbon black, plant-based dyes, and any adhesive agent).

T tool (Production Tool): Specific type of implement used for applying the pigment. This is a critical factor and likely one of two main options (or a combination):

T pole (Long Pole/Arrow): A long, rigid object used for reaching the ceiling.

T stamp (Applicator/Stamp): A separate piece (e.g., wood, leather, yucca leaves) attached to the pole/arrow, possibly a stencil or a stamp for repetitive application.

M tech (Artistic Method/Technique): The precise sequence of steps for applying the image at height:

M stnc (Stenciling): Use of a template held against the rock for filling in the design.

M stmp (Stamping): Direct, repetitive pressing of a pigment-loaded tool/stamp onto the surface.

3. Production Algorithm (A Navajo star ceiling)

A Navajo star ceiling = Minimize (Effort) Subject to Reaching C hgt and Producing A form

1. Preparation Phase (Known → Unknown)

Input: V Known (especially C hgt, P col, A form)

Determine P comp: Analyze P col to infer raw materials and binder needed for high-adhesion and long-lasting quality.

Design T tool: Based on A form (cross shape) and A meth (stamping/painting), design T tool as a stamp/stencil attached to a long reach mechanism (Pole/Arrow).

2. Application Phase (Variable Unknown → Action)

Set T tool Length: $L_{\text{tool}} \approx C_{\text{hgt}} - \text{Artist Height}$

Load Pigment: Apply prepared P comp (pigment) to the application end of T tool

Execution (Iterative Loop): While Star Count < Target Number:

Implement M tech: Using T tool, execute the chosen method (M stmp or M stnc) by reaching up to C hgt

Place Star: Apply the star form (A form) to the rock ceiling C loc

Advance: Move the application point to the next desired location.

End Loop.” (Gemini Pro, 10/26/25, response)

This response from AI brings to the fore the cognitive and behavioral aspects needed for star ceiling production, thereby setting the stage for examining the process of star ceiling production in a novel way, thus highlighting the procedural features of making a star ceiling. Leaving aside certain ceremonial considerations, AI’s response here primes us to ask further questions about the artistic process itself, therefore expanding our ability to conceptualize the

artworks. As such, in the way that AI highlights the production sequence, these artworks are the final product of a prescribed activity or procedure.

In a way, this completely experimental engagement with AI regarding the development of an algorithm for star ceiling rock art production truly underscores and accentuates the fact that pictographic rock art production of any type, whether star ceiling or some other type of pictographic rock art, is a multi-step complex process that involves choosing the rock canvas, choosing the pigment, choosing the right set of tools for applying the paint, applying the paint, and more (IGNCA 2022). This insight aligns with the experimental procedure I conducted in 2011 based on the pictographs found at Site 2, where I created stamps and stencils modeled on the pictographs found at Site 2 and attempted to reproduce the stamp/stencil-tipped arrow technique that may have been used to produce the original pictographs (Christian 2012:104-109). The experimental replication demonstrated the feasibility of this method but also highlighted the procedural aspects of the technique as well.

Results of Experimentation with Virtual Reality

At Site 2, a professional 360° camera (Insta360 Pro 2) and a drone (DJI's Mini 4 Pro) were both used to capture digital images for the VR construction. The site was recorded as a series of 360° panoramas to simulate a walk-through experience within the cave. The 360° camera used six 200° lenses to capture the full environment, via a photogrammetry-capture process. A couple of other archaeological features adjacent to Site 2, the alcove and rock art panel located approximately 1/2 mile to the west, were also included in this VR rendition, adding a landscape-type perspective to the VR environment and VR experience. The drone was used to capture aerial vantage points of the site, including 360° panoramas that support directional context from above the cave environment itself.

The results are astounding. They confirm several items of note: The VR capture process was successful. It only took two hours to complete once we arrived at Site 2—after having dodged two winter storms and spending much time off-roading to actually get to the site. Most of the two hours was spent preparing, setting up equipment, and placing the cameras and drone in the appropriate and ideal locations for the best digital panorama and drone capture possible.

Broadly speaking, and immediately noteworthy, is the fact that the VR environment is not only useful for digital site preservation—which may not be too surprising since it creates a digital twin of the site—but it is also useful for observing and understanding site change over time. This effect is immediately apparent in cross-comparing pictures taken in 2011 with the VR rendition completed in early 2026 (Figures 43 and 44). More on this is in the Analysis chapter.



Figure 43: Photograph of bird-like pictograph found in Site 2 in 2011. Photo taken by author.



Figure 44: Screenshot of VR image of the same bird-like pictograph found in Site 2. This image was produced in 2026. The effect of the differences, reflecting changes to the pictograph over time, are more apparent in the VR environment. The red is dulled and the pictograph looks to have been obscured by an overlay of mud. Screenshot by author.

The VR environment creates the ability to enter the site at any time, from anywhere, and to remain at the site for however long a researcher wishes to stay. That is to say, the VR environment allows for consistent observation of the site and repeated observation for any length of time necessary to answer various hypotheses about the site. This aspect of VR expands the aperture of time for researchers while also making research a bit more convenient because one does not need to worry about time constraints, weather, logistics, etc.

In line with the above, the VR landscape allows researchers to focus on any feature of the site in a way that can support inquiry, data collection, and interpretation. With the mudballs, for instance, a researcher can spend as much time as is needed, without any of the in-the-field constraints normal to archaeological field investigation, to count every single mudball on the ceiling, and more.

Additionally, the Site 2 VR environment is highly conducive to supporting educational and public archaeology goals. There is the ability to add descriptive detail into the VR environment to describe any number of archaeological/geological/historical features. That is, the digital representation of Site 2 can not only immerse people into the site itself, but it can also immerse people into the data about the site by creating accessible informational content contained within the VR rendition. The content can be accessed through “hotspots” within the VR world where participants can access details about the site, informing their VR experience (Figures 45 and 46).

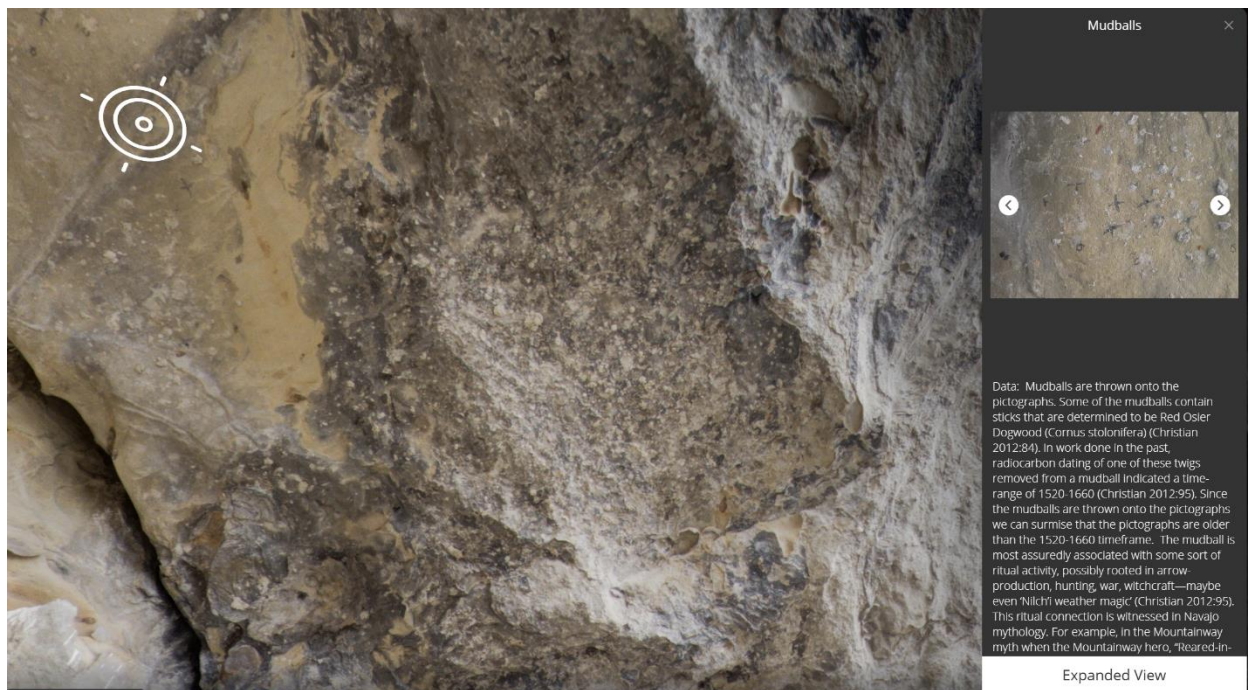


Figure 45: Example of a VR hotspot as seen in this screenshot of the VR rendition of Site 2. This hotspot highlights the mudballs. Screenshot by author.



Figure 46: Another example of a VR hotspot as seen in this screenshot of the VR rendition of Site 2. This hotspot highlights a star. Screenshot by author.

The use of a drone to support the VR construction of Site 2 offers accessibility to specific locations within Site 2 that have been historically out of reach, including small alcoves found at unreachable heights and pictographs painted on the ceiling placed at heights of 15–60 feet (Figure 47). It seems likely that some pictographs seen from this perspective are newly recorded simply because no one could reach them.

Lastly, though there are a lot of positive attributes to creating a VR rendition of a rock art site, like Site 2, there are some notable limitations as well. For example, the quality of the VR experience is proportional to the quality of the technology being used to capture a site. Palonka and colleagues (2023), though they didn't create a VR rendition per se, used LiDAR techniques in their 3D reconstruction of an important rock art site in Colorado, and the level of detail is extremely sharp. For this thesis, however, the VR capture process was rooted in a type of

photogrammetry procedure, by way of the six-lensed 360° camera. This process captured a lot of detail together with the ambiance/feel of the site, but sharp detail is somewhat limited in certain areas of Site 2 that contain pictographs. And, admittedly and importantly, sharp detail is needed for rock art studies in general. Notwithstanding, a 3D secured webpage was created from the 360° photogrammetry process, and this forms the visual basis of the constructed VR environment for Site 2; curiously, the level of detail in this 3D rendition, at certain places, is a bit sharper than the final VR rendition. (The secured 3D webpage will be provided to the Thesis Committee for review.)



Figure 47: Drone photograph of the interior of Site 2 taken from above Site 2's entrance at heights over 70 feet. Photo taken by Jay Salois, VR contractor, for the purposes of this thesis and used with his permission.



Figure 48: Drone photograph of the interior of a small alcove located above Site 2's entrance at heights over 70 feet. Though no material culture is present here, this photograph shows a close-up of a section of Site 2 that is completely inaccessible. Photo taken by Jay Salois, VR contractor, for the purposes of this thesis and used with his permission.



Figure 49: Screenshot of a VR perspective from the entrance of Site 2. Image by author.



Figure 50: Screenshot of a VR perspective from the entrance of Site 2. Image by author.



Figure 51: Closeup photo taken by drone during the VR recording of Site 2, at approximately 50 feet. Notice the vibrancy of the red pictographs in the middle upper of photograph. There are also some black pictographs that have not been seen before in the center of the photograph. Photo taken by Jay Salois, VR contractor, for the purposes of this thesis and used with his permission.

Consultation with Conservator

To ensure the long-term integrity of these special sites, especially with the increasing threat of environmental changes and other factors, a professional conservationist was consulted to attempt to create a theoretical preventive conservation plan as a way to prescribe non-destructive conservation interventions. Longtime professional conservator and professor, Victoria Clow, provided her recommendations and they are worth highlighting in this results chapter.

Professor Clow's main preservation thrust is in line with what is called "passive intervention" (personal communication 2025). She based her preventive conservation plan in line with general and accepted preservation activities, vis-à-vis Site 1 and Site 2, and these passive interventions are centered on "keeping people and environmental degradation away from the artworks" (personal communication 2025). The passive interventions in this case include the following: 1) performing a risk assessment for potential harm; 2) using blockading features to prevent access to the sites; 3) obscuring the sites from view as a measure to keep people out; 4) using cameras to help observe and protect the sites; 5) using screening and other shading devices to prevent sun, wind, and water damage; and 6) building roofs over the sites and using other mechanisms, to prevent solar, wind, and water damage.

Professor Clow did mention more active interventions—as opposed to passive interventions—which might include chemical preservation and conservation techniques; these techniques would include actual chemical assessments of the pictographic pigments, chemical cleaning, and chemical conservation/prevention treatments such as varnishes and the like.

Summarizing Remarks

The results presented here point to the fact that the methods employed in this thesis were valuable for data collection. These results confirm that the multi-methods approach used for this thesis is more than adequate for answering the research questions that guided the entire research effort. In the next chapter I will highlight the patterns of meaning associated with the data via an in-depth analysis of the data and the methods used to complete the data collection. This analysis will highlight important trends associated with Site 1 and Site 2 and the artworks found at these sites.

Though these results are promising, especially with respect to the experimental techniques employed via AI and VR, there are ethical considerations that must seriously be considered when using these methods with sacred artworks that can be classified as cultural patrimony. This fact extends the philosophical and ethical obligations of the researcher, requiring serious reflection on how digital enhancement, digital reconstruction, and digital storage may impact the cultural meanings of the artworks being studied.

Chapter 6: Analysis

Foundational Thoughts on Analysis for This Thesis

I set out in this thesis to examine two star ceiling sites by utilizing a multi-methods approach that capitalized on a panoply of research tools, including fieldnotes, sketches, photography, pXRF, AI, and VR, as well as pollen analysis of a mano from one of the sites. My goal was to gather as much data as possible in an effort to support both increased knowledge about star ceilings and increased understanding about these technologies themselves and their ability to enable research, conservation, and preservation activities. As such, my main thesis question guiding this research project is: How can combining traditional rock art research techniques, such as fieldnotes and photography, together with modern technologies, like pXRF pigment analysis, AI, and VR, provide new insights into the material choices, ritual painting processes, and digital research and preservation of Navajo star ceilings, and what does this reveal about the potential usefulness of emerging digital tools for documenting, conserving, and preserving ancient rock art?

To analyze the data uncovered in this broad-ranging multi-methods approach in a meaningful way, I categorize my analysis of the data, moving from each individual technique to a broader analysis that encompasses a general interpretation of the entire data-collection work. This analysis is meant to answer the following set of research questions that have guided this study:

1) What can a modern analytical instrument like pXRF—a data collection technique that has not been used with Navajo star ceilings—tell us about the pigments used at two distinct star ceiling sites? 2) How can this new data support deeper understanding of star ceiling sites in

general and the ritual activities performed at these sites? 3) How can this data support potential preservation techniques and inform preventive conservation activities? 4) How do emerging technologies, like AI and VR, support digital restoration/reconstruction and preservation of these sacred artworks? 5) Lastly, though there is a lot of positive energy about these emerging technologies and their capability to support archaeological research, are they indeed practicable and useful when it comes to investigating rock art and star ceilings?

Analysis of Recordation, Fieldnotes, Sketches, and Photography

The analysis of the fieldnotes and sketches offers some interesting viewpoints. There is a huge difference between Site 1 and Site 2 with respect to the size of the sites and the frequency of the star pictographs. This set of differences is rooted in the fact that each site is distinct in its own right. For instance, the height range in Site 1, Alcove 2 is 18 to 31 inches, thus requiring that the artist crawl underneath the alcove ceiling to create the star pictographs on display there. In fact, it is highly likely that the artist was lying on their back to create the artworks on display at Site 1, Alcove 2, and it seems likely too that the artist made these stars by hand (perhaps with a piece of burnt bone as suggested by pXRF analysis, discussed below).

In contrast, Site 2's ceiling is extremely high. It forms an almost perfect arch, 60 feet high at its apex. This means the artworks made at Site 2 were produced using other methods, including some potentially hand-painted pictographs to pictographs likely made with stencils and arrows that were shot onto the uppermost portions of the ceiling (Jett 1984:25-40). Also, whereas Site 2 exhibits close to 200 pictographs, Site 1 exhibits only six stars in total.

These stark differences between Site 1 and Site 2 highlight the potential that the two sites were used for differing purposes. Site 1 is a smaller site and seems more personal, perhaps

indicating use of the site by fewer people, while Site 2 is much larger and grander, perhaps pointing toward a kind of communal use of the site.

Notwithstanding their differences, details of each site are similar and these similarities are worth pointing out as well: Both Site 1 and Site 2 face south. That is to say, the cave/alcove openings (the cave/alcove mouths) face a southerly direction. This follows the pattern witnessed in Mesa Verde where the “rule” is that pueblo structures are built in south and southeast-facing alcoves (Palonka 2019:251). Lightfoot (1994) corroborates this south-facing orientation with his notion that south-facing caves and alcoves provide a microclimate advantage where heat from the low winter sun is captured during cold months while remaining naturally shaded in hot summer months. I have long thought that Site 2’s orientation had some significance related to solar alignments (Christian 2012), but it is also possible that these sites were used for their star alignments in that if they were occupied during the winter months, it is probable that members of the tribe were observing not only the winter day sky but the winter night sky as well.

What is more, both sites sit at similar elevations above sea level, 6,500+ feet. They are also both located within the old *Dinétaah* landscape—that is, “among the *Diné*”—the “place where the Navajo people came to be following their emergence into this current world” (Campbell and Forton 2023:44). In other words, both Site 1 and Site 2 are located in the traditional Navajo landscape, that landscape occupied before the Navajo became circumscribed within the current Navajo reservation. It is at least plausible, given the known movement of the Navajo people from the *Dinétaah* onto the Navajo reservation, that both Site 1 and Site 2 are representative of an older style of star ceiling, and that versions witnessed in Canyon De Chelly and in other parts of the Navajo reservation are characteristic of newer forms of this type of rock art, representing movement from the old homeland to the new homeland over time.

Too, there is something extremely intriguing about the pattern of consistency with the pictographic star sizes, especially as witnessed at Site 1. These pictographs are not perfectly equilateral but there is a tendency to create a uniform equilaterally sized star throughout Site 1.

Site 2's pictographs are harder to measure because most of the pictographs are located scores of feet above our ability to reach them. But there is evidence of this same tendency to create equilateral crosses at Site 2.

Because of this complementarity, for the lack of a better word, and consistency between the star pictographs' lengths and heights, I truly do wonder if there is a kind of preset or standardized cognitive pattern or a concretized iconographic/ritual artistic pattern, or both, related to star pictographic artworks. In other words, there is a particular intentionality with the creation of these pictographs that speaks to a model or type or form.

Indeed, this iconographic form is still witnessed in Navajo jewelry, Navajo pottery, and Navajo weavings and rug design (Figure 52). Inasmuch as we can get into the minds of the artists themselves, it is possible to hypothesize, based on the results of this small study, that they were intentionally attempting to make a type of standardized star pictograph. I wonder if, as Boyd and Busby (2022) describe, this potential standardization is rooted in a type of artistic and iconographic narrative. Or as Bayrak notes, these symbols may be standardized because they act as a type of "memory aid" that visually communicates the collective memory of the Navajo people (2025:1964), especially as it relates to the themes of stars and the night sky.



Figure 52: Navajo rug made by Bobbijo Whitehair entitled "Sunrise Pictorial." This is a modern Navajo rug depicting cruciform star icons, as seen during sunrise. Image courtesy of Bobbijo Whitehair and Garland's Rugs.

Further, and interestingly, at Site 1 a distinctive pattern is discernable in the distribution of star pictographs, a potential constellatory star pattern. We can infer that this pattern is known to the Navajo people, and it is a pattern that is reminiscent of Orion. In Navajo culture, the western constellation of Orion is known as “Slender First One” (Haile 1947:4). If this rock art is indeed placed in a Navajo constellation pattern, then much more can be said about its significance and the significance of the site itself.

Because the actual stars of the night sky are in a state of perpetual motion, there is an inherent dynamism embedded in symbolic star patterns and constellations (Figures 53 and 54). Boyd and Busby (2022) argue that rock art is a type of vocabulary painted on stone. I suspect that this potential constellation pattern is communicating something vital and dynamic within the Navajo cultural context. In other words, this potential pattern may be “encoded” with distinct and special meaning for the Navajo people (Bayrak 2025:1963). It’s possible, too, that this pattern may form a type of iconographic language, or “semasiography,” a symbolic visual language seen in pictographic rock art that communicates meaning and ideas directly through symbols as opposed to communicating meaning and ideas phonetically (Mikulska 2020:9).

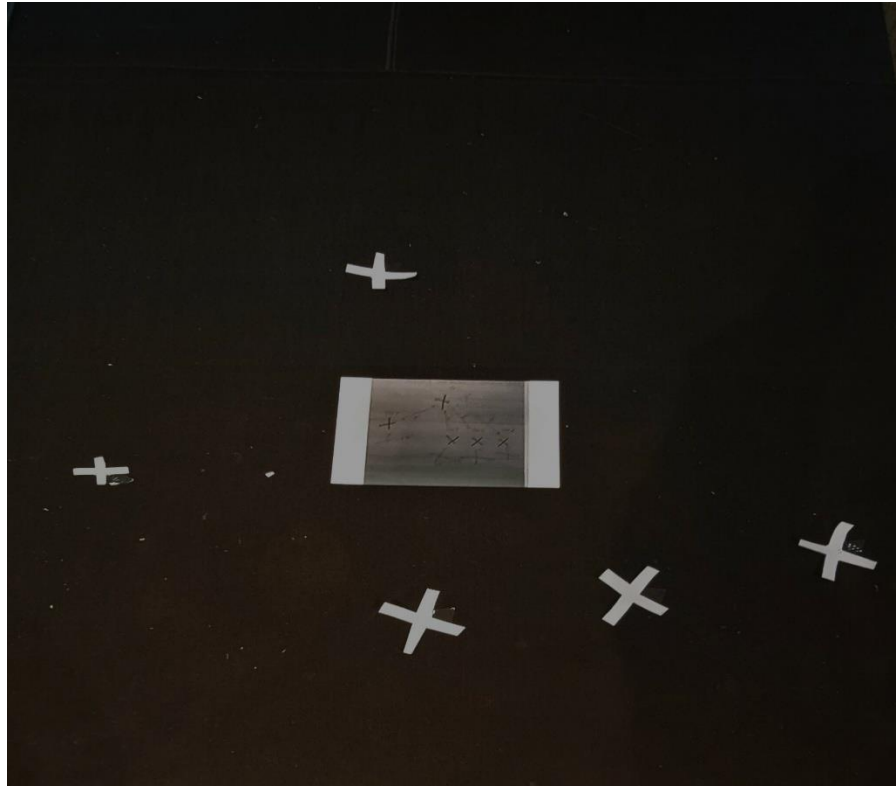


Figure 53: Potential constellation pattern as witnessed in my fieldnotes and sketches at Site 1, Alcove 2. This image was created by Stephen Townley Bassett, artist and experimental archaeologist located in South Africa who works with ancient rock art to understand ancient artists (personal communication 2026). Bassett's expertise is with ancient African rock art but he assisted me in understanding rock art painting techniques. Here he juxtaposed my sketch of the star pattern with his enlarged rendition of the pattern, a technique he has perfected with African rock art.



Figure 54: Photograph of Orion's belt during the winter months from Western North America. This view is looking southerly, imitating the view from a supine position as is theorized for Site 1, Alcove 2. Notice the distinctive three stars found in a row located at bottom center and the two brighter stars in the upper portions of the picture. Photo taken by author (January 04, 2026, Ramah, New Mexico).

Importantly, a vein of bentonite clay is on view at Site 1, Alcove 2 as well, in the interior of the alcove, situated more interiorly to the five stars found in this alcove (Figure 55). The question that comes to mind is whether Site 1, Alcove 2 served as a bentonite clay quarry, and perhaps the pictographs are somehow related to the bentonite clay; or perhaps they are placed near the bentonite clay vein for some vital practical or symbolic reason. Bentonite clay is important to the Navajo people. In point of fact, bentonite clay is still sold across the Navajo Nation and the Four Corners region (Native Americans Albuquerque Network 2026).



Figure 55: Bentonite clay/*Gleesh* vein as seen in the interior of Site 1, Alcove 2. This vein is witnessed in the bluish gray soft rock situated in the center right of photograph. The five stars are positioned near the photographer. Photo taken by author.

During an informal conversation with an older Navajo woman, she explained that, “*Gleesh* [bentonite clay] is used in the *Kinaalda* ceremony [puberty rites for girls] and is closely associated with Changing Woman. It is also used to dye wool for weaving and in other paints. And it is used in rain ceremonies too” (personal communication 2025). Curiously, this same woman also described the Navajo Lake region, the area where Site 1 is located, in the following way: “This area used to be the center of the Navajo world. Some of the older ones think that the Navajo people are losing their language and culture because of the flooding of that area to make the Lake” (personal communication 2025).

Another woman heard me describing this bentonite clay vein near the star pictographs and she said it was, “*nizhóní* [Beautiful/Awesome]” (personal communication 2025). She later stated to me that the bentonite clay is “the Milky Way” and the stars are “First Woman,” another Navajo constellation comprising what we know of as Cassiopea (personal communication 2025). First Woman, together with First Man, are thought to be the creators of the heavens and the earth in Navajo mythology; they created the stars and the sun and the moon (Zolbrod 1984:90).

The real symbolic significance of Site 1, Alcove 2 may never really be known, but we can assert that there is something important happening here with these cultural allusions. I’d like to think this site is representative of a sacred place where heaven and earth meet, where the star pictographs representing the night sky interconnect with the vein of bentonite clay representing the earth.

With respect to the digital photographic inventory, in general, the digital photographic recordation process was biased toward Site 1, as mentioned in the Results chapter, even though Site 2 is larger and in some ways more complex. The main driver for this difference, as described previously, is the fact that Site 2’s pictographs are located way above arms’ length, and I could not access many of these pictographs (even though we did attempt to use a ladder). What’s more, I had already performed heavy photographic documentation of Site 2 in the past (Christian 2012:48-53; Figure 56).

What this means from a practical standpoint is that the photographic documentation for this thesis reflects the tendency to put more digital photographic attention on Site 1. Site 1 is also undocumented with the State, which makes it something of a raw template for new research. Notwithstanding, the photographic analysis assisted with providing a visual context of the sites,

up-close viewing of individual pictographs, and inventorying pictographs especially by way of the pXRF analysis.

Frequencies of Pigment Use in Pictographs in Pinestaja Cave Site

Color	Frequencies of Colors
Black	137 pictographs
Red	47 pictographs
Black/red Combined	1 pictograph
Yellow	3 pictographs
Gray	1 pictograph
White	4 pictographs

Figure 56: Frequencies of pigment colors from Site 2 as obtained from photographic analysis of Site 2 (*Pinestaja* is a pseudonym for Site 2) (Christian 2012:52). Reproduced with permission from the author.

Apart from this, the distinct characteristics of the pictograph labeled Site 2, Star 1, by way of the photographic evidence, point to the notion that this individual pictograph may have been painted with the artist's finger. This is a different artistic technique than the other recorded pictographs on view at both Site 1 and Site 2. Stencils, stencil-tipped arrows, and other methods, such as charcoal and/or burnt bone, were likely used to create the other pictographs on display at Site 1 and on the ceiling of Site 2. In other words, a kind of mix of artistic techniques was employed at both sites. This difference, or diversity, in artistic techniques with respect to these pictographs is of deep interest and could sustain further research.

Also, the fieldwork underscores the fact that each pictograph represents the end of a distinct process—the conclusion of a procedure—that included harvesting minerals for pigments, making the paint, making the tools to paint the pictographs, choosing the rock canvas, and so on; that is to say, certain distinct behaviors form each step of the painting process. From a cognitive and behavioral perspective, the thoughts and actions needed to create these artworks are distinctive, and the types of paints and tools needed to create these artworks are also distinctive. This line of inquiry can likewise help support further research into the potential meanings of these pictographs.

It's also worth noting that there are often clear boundaries between the painted images and the unpainted rock; that is to say, the margins between the painted pictographs and the rock canvas are highly differentiated—they are sharp and very precise. I hypothesize that this clear demarcation between the painted icon and the unpainted rock canvas is intentional and may point to an important type of Navajo cultural and artistic tradition (Walters 2024).

Analysis of Other Archaeological Features and Artifacts

The abundance of presumed Puebloan petroglyphs found at Site 1, together with the Navajo pictographs and other features, highlight that this site was repeatedly visited and used over long periods of time. As mentioned, all of these petroglyphs are in the style that Schaafsma calls “Type I and Type II” Pueblo petroglyphs (her designations for this style), described by her as typically representing “broad-shouldered men” averaging one to three feet in height (1963:26, 28). These, according to Schaafsma, predate the star pictographs witnessed in this thesis (1963:37), and they are related to what Schaafsma says is the Basketmaker III to Pueblo I time periods, roughly 700–900 AD (1963:31). In other words, and according to Schaafsma, this site was known to people across generations and across cultural boundaries (1963).

Though we can't at the present time prove its temporal connection to the pictographs and petroglyphs, the hearth and grinding stones found in Site 1, Alcove 1 point to food processing activities and perhaps ritual activities involving the petroglyphs and pictographs. Site 1, Alcove 1 contains one star, known as Site 1, Star 6 in this thesis. This star is in very close proximity to the hearth and grinding stones and is in some important way associated with the fire, food production, and the other activities taking place in Site 1, Alcove 1.

Curiously, the North Star in the Navajo mythic complex is known as "North Fire," and Site 1, Star 6 is located in the north section of Site 1, Alcove 1 (Monroe and Williamson 1987:31). North Fire is symbolically associated with the central fire of the hogan, the Navajo traditional home (Griffin-Pierce 1992). Site 1, Star 6 could be interpreted as the North Star shining within this alcove. Too, it's easy to imagine the visual effect of firelight from the hearth dancing off of this pictographic star at night.

On top of this, it does seem highly probable that Site 1 acted as some kind of bentonite clay quarry. Its close proximity to the five pictographs highlights a literal adjacency and potential symbolic as well as physical association between the stars and the bentonite clay.

Like Site 1, Site 2 also shows repeated use over time, with its Puebloan and Navajo archaeological material together with the evidence of a modern homestead. Also, like Site 1, Site 2 was repeatedly visited and used over long stretches of time, and was known by many generations of people, even people from differing cultures.

Moreover, it is at least possible that the arrow-shaped petroglyphs found at Site 2, witnessed in the boulders situated on the ground below Site 2's pictographs, may indicate a relationship between the ritual activities related to the pictographs; and perhaps these activities are associated with arrow production, arrow-straightening, or some other ritual activity

(Christian 2012:87). In research performed by the author in the past, Red Osier Dogwood was found inserted into a mudball that was thrown onto the ceiling of Site 2, and Red Osier Dogwood is connected with arrow production and ritual emetic behavior, among other ritual activities, in the Navajo culture tradition (Christian 2012:95-96; Kluckhohn 1944:27; Kluckhohn et al. 1971).

In addition, the abundance of mudballs exhibited on the southeastern portions of Site 2's ceiling continues to offer me an enduring fascination. I have concluded in research performed in the past that these are representative of some form of weather magic, as witnessed in Navajo myths (Christian 2012). In particular, the Mountain Chant, a healing ritual that can also be used to bring rain and magically support crops, features mudball creation and use as a way to harness the power of the weather to defeat enemies (Matthews 1997).

At its base, though, these mudballs indicate a clearly defined set of activities whose meaning may be completely unknown: Mud was created from the spring in Site 2, it was formed into a ball-like mass about the size of a fist, twigs were inserted into these balls, and then they were thrown onto the ceiling, in many cases on top of already-produced pictographs. One twig extracted from a mudball found at Site 2, in prior research, was radiocarbon dated to 1520-1660 AD (Christian 2012:80). Even though they look like they were thrown onto the ceiling last week, they are close to 500 years old. I think these mudballs are part-and-parcel of ritualized activities, but it may be possible that these were created to serve as a type of game. Much more research can be done with these mudballs to elucidate their function and meaning.

As an aside, the artworks found adjacent to Site 2 are important and of deep research interest and value. They point to a landscape that is something akin to a symbolic template or canvas. Like Site 1, these artworks most likely span generations and culture groups, as well as

iconographic symbols, but they also underscore the value that this landscape had for the artists who created art here.

Analysis of Pollen from a Mano at Site 1

The material found on the mano truly does correspond with the plants found outside and near to Site 1, suggesting that the people who used the site were gathering plant material from around the site. The pollen analysis also reveals that corn was not part-and-parcel of the plants being ground by this mano. The geographical area surrounding Site 1, as mentioned in the Results section, is not conducive to farming, so it's not surprising that corn is not present on the mano. By extension, the particular plants represented in the pollen analysis of the mano from Site 1 suggests that these plants are wild plants, specifically selected for use at Site 1.

Though we cannot temporally associate the mano with the star found in Site 1, Alcove 1, it is interesting to attempt to correlate the grinding of plants with the production and/or use of the star. For instance, Hollowell (1948:13), in her description of Navajo rug dye production, tells how Pinion Pine tree pitch is used to create black dye among the Navajo for their weavings. Since the pollen analysis of the mano reveals the presence of Pinion Pine, it is possible that Pinion Pine tree matter from the mano may have formed some part of the black pigment seen in Site 1, Star 6.

The grinding of grass seeds evidenced at Site 1 points to the fact that perhaps this site was used during certain times of the year, as grass seeds, among other types of seed, are only available during particular times in the year. Sagebrush, for instance, seeds in the Fall in New Mexico when the other wild grasses are dried out (BLM 2024).

Questions to consider from a landscape perspective is whether Site 1 served as a temporary camping site or some other temporary ritual site. Since the petroglyphs are presumed

to be Puebloan (Schaafsma 1963), the site was used over long stretches of time, but how was it used? Is this site a hunting site? A sacred ritual site where people could engage with the power of the pictographic stars on view at Site 1? Or was it part-and-parcel of bentonite clay quarrying activities, among other things?

Analysis of pXRF

There is a great deal of data pertaining to the pXRF analysis of the pictographs at Site 1 and Site 2. This data can serve as foundational data for more research in the future. The analysis of the results of this data indicates meaningful patterns.

Far Western performed the in-the-field pXRF data-collection activity, and Far Western provided the initial interpretation of this data. I also consulted with INFRA-ART to expand on the initial results provided by Far Western. Though INFRA-ART corroborated the interpretations provided by Far Western, INFRA-ART offered a more detailed set of interpretations based on the data. This fact highlights that pXRF data can be mined for patterns and meanings based upon the dual effects of the XRF interpreter's experience and access to other associational spectral data. That is to say, pXRF data is amenable to cross-comparative activity to deepen its significance. Therefore, INFRA-ART could make richer interpretations based on the data because INFRA-ART has access to spectral data from across the globe.

One important limitation to pXRF is the fact that the breadth of interpretation is based on the experience of the analyst and the database used to compare the spectral data. This means that we can have varying results and analysis based on the limitations and/or robustness of the spectral data that analyzed data is compared to.

The primary element found in the pigments exhibited at Site 1 and Site 2 is iron-based. The iron-based material used in the red pigments is comprised of hematite or red ochre.

Alternatively, magnetite is an important iron-based material found in many of the black pictographs. Taken together, there is a great deal of iron in these pictographs, and it is iron from specific types of rock.

In general, humans have a very long history of using red ochre for a number of artistic and ritual activities (Gustafson 2023). Indeed, red ochre is a very important substance for the Navajo people in particular. It is often used as a body paint, among other ritualistic activities, and in the Navajo language is known as *Chiih* (Navajo Grandma 2022); the fact that it is found in pictographic pigments allows for an interpretative bridge between Navajo body painting and Navajo rock art.

While magnetite is used for many of the black pictographs (Far Western 2025), there are some black pictographs present at Site 2 that contain manganese-rich earth, galena or lead, and bone black (Cortea 2025). The manganese is found in the Amorphous black pictograph located at Site 2 and is an outlier, not found anywhere else. The use of lead is found in the black ring around the solar pictograph in the alcove adjacent to Site 2. This is also a unique finding within pictographs examined at Sites 1 and 2. In fact, it is suggested by INFRA-ART that this is evidence of a modern *retouche*/reworking of this ancient pictograph, since lead is a modern additive to paint (Cortea 2025) and is known to be a paint additive in the United States since the early 1800s (Gawrych et al. 2023); this suggests ongoing visitation to, and reworking of, this particular pictographic artwork.

Bone black is found primarily at Site 1, Alcove 2 (the five stars) together with the black Bear and black Chicken found at the site adjacent to Site 2—the very same place where the *retouche* on the solar pictograph with lead paint took place. In point of fact, the bone black found

in the Bear contains hydroxyapatite, a mineral found in animal bone strongly suggesting that animal bone was used in the making of this pictograph (Cortea 2025:3).

Likewise, two of the Stars at Site 1, Alcove 2 show high arsenic levels that are also suggestive of animal bone being used in these pictographs (Cortea 2025:3). It is entirely possible that the artists used burnt bone to serve as the painting applicator tool at this site.

In addition to these findings, there are geological “provenance trace markers” present in many of the pictographs (Cortea 2025:2). For instance, Site 2, Star 2 contains high amounts of chlorine, chromium, and niobium, which can support finding the geological and geographical source for the material that comprises the pigment. Also, the mercury found in the solar ray situated adjacent to Site 2 can be used as a “useful trace marker” (Cortea 2025:2). The bromine found in Site 2, Star 1 can likewise support finding the geologic source of the pigment. What’s more, the unique signature of Site 1, Star 6 reveals that this black star may have been repainted at some point in the past (Cortea 2025:3).

I must emphasize that a few of these artworks have been reworked at different points over time. This is an incredible result pointing to the continuity of both the retained memory related to these sites and the associated meanings connected with these sites. There is, therefore, a kind of sacred artistic activity associated with the artworks, together with a kind of vital connection between different artists over long periods of time and connected by the iconography and the sites themselves. Vitally, this characteristic may point to a collective memory associated with these sites, one that transmits a collective “visual archive” that has the power to persist over long periods of time (Bayrak 2025:1962).

Crucially, the mudballs found on the ceiling in Site 2 were indeed made with the mud found within the perennial spring contained at Site 2. This is also a wonderful fact. We can

assume this to be the case, but the pXRF analysis has proved that the mudballs were made below the cave's ceiling and thrown onto the ceiling right there within the precincts of Site 2. The mud was collected there, the mudballs were produced there, and they were subsequently thrown onto the ceiling there.

On top of this, the artists of these pictographs had knowledge about pigments and about various iconographic symbols, especially star symbols. The artists knew how to create pigments that would last for generations, and because of this special knowledge about pigments it is obvious that they knew where to mine the minerals to create the differing pigment colors witnessed in these artworks.

Relatedly, the Navajo are known to have access to a repertoire of naturally found dyes that can create a full palette of color (Hollowell 1948), so I argue that the choice of red and black pigments is significant. It is possible that these colors are associated with warfare and hunting (Christian 2012:113). Likewise, it's possible that these chosen colors are associated with certain ritual activities, like body painting and arrow ornamentation (Christian 2012:113).

Analysis Using Emerging Technologies: Artificial Intelligence and Virtual Reality

Analysis with Artificial Intelligence

a) i. AI reconstructing image with digital paint:

In this case, Gemini Pro was used to create a type of AI-directed digital restoration of two pictographs from Site 2. The analysis of this experimental procedure is as follows:

Using AI to reconstruct pictographic images of rock art is still novel and, based on the results of this small experiment, is effective for reconstruction, as well as conservation and

preservation activities. What is more, this is a non-destructive digital technique to perform research, conservation, and preservation activities.

The results indicate that this AI repainting/reconstruction process can support further research as well. The AI-reconstructed images facilitate visual clarity and support the identification of certain details like the original boundary lines of the artwork in an enhanced way.

There are certain risks related to site confidentiality. For this reason, this research meticulously maintained absolute anonymity with AI vis-à-vis the site's sensitive location information and other details.

Even so, there are some real ethical issues surrounding this type of work. Though star ceilings are found within the broad world of the internet, there are deep ethical considerations related to digital stewardship and digital sovereignty apropos of “feeding” Gemini Pro images of potentially sacred artworks (United Nations 2023). I was blinded by the potential of this technology, so much so that beyond my careful, ethically grounded approach to the use of the technology, I did not consider the deeper philosophical ramifications. In this way, rock art can serve as a jumping off place for examining the nuanced ethics of using AI in archaeology and CRM. In addition to this, and given the importance and gravitas of the definition of cultural patrimony (Navajo American Graves Protection and Repatriation Act of 1990), the ethics surrounding using AI enhancements with sacred rock art images of a particular culture—in this case, the Navajo culture—need to be carefully and expertly examined and articulated. For instance, is it right to use AI to manipulate potentially sacred images that belong to a particular culture group?

ii. Reconstructing images by removing the background of artworks with AI:

For this method, Ximilar's AI platform was used to refine images by removing the respective backgrounds of the pictographic images. The analysis of this procedure is as follows:

Like the AI-reconstruction with digital paint, this method of creating a reconstructed image of the pictographs by removing/extracting the pictographs from the rock canvas background, or separating the pictographs from the background, is novel and shows promise in rock art research. Furthermore, this technique is a non-destructive method to perform research, conservation, and preservation activities.

Though it's a somewhat simple process, the visual effects are interesting and highlight that digitally separating the pictograph from the rock canvas really does help to visually isolate and target the pictograph itself, thus supporting seeing the pictograph in new ways, forming a different perspective, and seeing detail that would perhaps go unseen. For example, two pictographs were used for this piece of the study, and after removing their respective backgrounds, one can notice that the characteristics of the centers of these pictographs are better viewed without the background; that is, with their respective backgrounds removed, there is a certain clarity to the pictographs' forms. Additionally, the centers of these pictographs are distinctive, one with a clear hole in the center and the other with a kind of circular indent in the center, and with the backgrounds removed one can see these features better. As a result, these observations may support hypotheses related to how these pictographs were produced.

The same site confidentiality and ethical considerations with the AI-generated paint reconstruction exhibited above are witnessed in this procedure as well. Much more work needs to be done to examine ethics and AI, especially with respect to ancient rock art.

b) Restoring a pictograph with AI

Digital restoration analysis is as follows:

This approach to restoration with rock art is novel. In fact, this portion of the thesis work was entirely experimental and meant to act as a type of proof-of-concept approach to new methods of supporting digital conservation and preservation in rock art studies.

Mr. Kashkin's model is designed for three-dimensional restoration of actual paintings, so using a two-dimensional digital image was not an appropriate match for his AI model (Kashkin, personal communication 2025). This fact led to the model having difficulty with recognizing and filling-in areas in the digital image that needed restoration. The final restored image did not create a perfected pictograph. On the contrary, this iteration of the AI-generated digital restoration made the pictograph look worse.

In my mind this experiment is a success, even if it wasn't successful with this particular iteration of digital pictographic restoration. This set of actions based on Kashkin's AI restoration model shows that rock art specialists, among others, can potentially train and harness AI's power to support digital restoration, thereby enabling a new type of AI-generated research, conservation, and preservation technique. In other words, researchers can work to create a model specifically designed to work with rock art.

To repeat, the ethics surrounding digitally enhancing and restoring sacred images that can be considered cultural patrimony must be considered carefully. It may be the case that tribal members do not want their sacred artworks to be replicated or digitally restored and preserved.

c) AI-created algorithm:

Again, this part of the thesis is absolutely experimental. As far as I can tell, via a review of the current literature on the topic, no one has asked AI to generate a rock art, or star ceiling, production algorithm.

Like the digital reconstruction with digital ink, this process was performed through Gemini AI. The analysis of this procedure is as follows:

This experiment serves as a demonstration of AI's capability in supporting research into rock art, especially star ceilings. The experiment underscores a shift in perspective from the artwork itself to the process needed to create the artwork. This is a subtle shift, but profound. The artwork is not the focus of this algorithm. Rather, the artwork forms the conclusion of a ritual process. This AI-generated algorithm, therefore, brings to the fore the fact that the art is a kind of output to a complex ritual procedure with many inputs.

This experiment is successful in that it opens the door to thinking about the making of star ceilings in entirely new ways. For instance, because of this algorithm we can entertain the idea about how much potential energy is needed to successfully shoot an arrow onto the ceiling in order to leave a pictographic imprint. Though not entirely novel, for me this is a new way to conceive of star ceiling production. In other words, this AI-generated algorithm supports other ways of conceptualizing the rock art and its production—alternative ways that can support researchers and their work to understand rock art in general and star ceilings in particular.

Indeed, what follows here is an example of my exact thoughts that I wrote down as a personal note following the processing of AI's response to me: "For star ceiling production, the energy needed to 'paint' pictographs with a stencil-tipped arrow: $\text{Potential Energy} = \text{Weight} \times \text{Height}$. If we use a 2lb arrow x 50' high = 100 lbs. of potential energy needed. The arrow will then need to fly at 56.75 ft per second which is something like 38 miles per hour, as Gemini AI puts it. You can calculate all kinds of equations to support the unpacking of computational data here" (author note to self 2025).

Taken together, and with respect to rock art studies and star ceilings, AI in this context serves as a powerful kind of brainstorming partner that can support cognitive flexibility when it comes to archaeological and scientific problems. As witnessed in this algorithm experiment, this AI-generated research support expands our ability to approach archaeological questions regarding certain sites. For me, Site 2 is a confounding site because of its height, so to elicit AI's support in thinking about the process of getting pictographs onto the highest heights of Site 2's ceiling is incredibly helpful.

Analysis with Virtual Reality Renderings

The VR rendition of Site 2 carries the most intense energy for me in this thesis. Though there are real and current efforts to document cultural heritage sites through VR and three-dimensional recording methods, these initiatives rarely focus on rock art exclusively (CyArk 2026; Meta 2025). As a result of this thesis project, I think there is potential in creating VR renderings of rock art sites like star ceilings.

Getting exposure to this technique has been thrilling, and I consider it to be a success from a few different angles. The general analysis of the VR components of this thesis is as follows:

The current technology truly does allow cameras to capture VR renderings of sites, successfully creating, with a high degree of verisimilitude, digital twins of sites. The Site 2 VR environment is incredibly rich and offers a type of genuine felt-sense immersion into the site.

The VR experience related to Site 2 also elicited feelings of awe. Importantly, there is already-established evidence of VR creating these experiences of awe in people within the VR environment (Quesnel and Riecke 2018). This awe-inspiring characteristic of VR can actually be

harnessed to support heritage conservation and preservation activities (Nascimento and Loureiro 2024).

VR facilitates researchers to enter into sites at any time they wish, for as long as they wish, as long as they have the ability to log into the VR program/application. This expands the ability to spend time researching at VR digital-representations of sites.

Likewise, via the VR environment, researchers do not need to worry about travel, weather, and other safety aspects associated with real-time field trips to sites, at least not after the site has been VR-recorded. In other words, there is a type of convenience with this method.

Research questions can also be constructed around, and investigated through, the VR environment itself, and the VR environment is conducive to intensive research. For instance, we can formulate research questions related to the mudballs found at Site 2, and via VR answer some of these research questions (like how many mudballs are found there). And going beyond this, there is evidence that research questions can even dive deeper into the presumed psychological and cognitive states of the original artists themselves as recorded in a VR environment (De Pisapia et al. 2024), highlighting unique approaches to archaeological research and inquiry via VR.

Not only this, but the time it takes to capture a site with VR is minimal. In this case, it took only approximately two hours to record three different rock art sites: Site 2, the alcove adjacent to Site 2, and a petroglyphic rock art panel closely associated with Site 2. After having spent years photographing and documenting Site 2 in the past, this two-hour timeframe absolutely impressed me.

Too, depending on the equipment, the site to be captured, and the type of research to be conducted, VR costs less than a field trip to a site. That is to say, one can capture a site with VR

cameras in a site visit that lasts only a matter of hours. This may not be helpful to traditional archaeologists, but to rock art specialists, this can really save time, effort, and money.

Respecting long-term data storage and access, Amazon Web Services was used to securely host the data obtained for the VR rendition of Site 2. To host a VR application like that used for Site 2, Amazon Web Services is more than adequate. It can support archaeologists and rock art specialists to host and archive this data directly and at a lower cost than some other web hosting options. An initial investment of \$3,000 to \$5,000 covers the custom build and deployment of a VR experience with an annual hosting fee projected to be about \$120 to \$500 per year. After the initial set up, the fee for five years of web hosting is comparable to the curation of one 1.2 cubic ft. box, at the low end, to four 1.2 cubic ft. boxes at the high end at Texas State University's Curation Facility (Center for Archaeological Studies 2026). On top of this, the data can be secured with password-protected firewalls to ensure archaeological sites' confidentiality; it can be opened for public access too, if the mission is to increase access and decrease barriers to heritage sites.

The VR rendering of Site 2 also reveals that VR is absolutely supportive of conservation, preservation, and education. The VR rendition of the site captures and maintains it in a distinct moment in time, recording something of the site's digital integrity, which can be valuable for various types of conservation, preservation, and educational activities. In some sense, too, it may be possible to describe this type of effort as a digital mitigation, making it a useful technique for certain archaeological survey and data-collection scenarios (Carrozzino et al. 2024).

Similarly, VR can support educational and public archaeology goals. There is the ability to add descriptive detail into the VR environment to describe any number of archaeological/geological/historical features. For the purposes of this study, the greatest

capability of the VR world may be rooted in its pedagogical/educational potential. This feature is described in the research literature (Stephan et al. 2025), but this thesis highlights VR's potential applicability in rock art educational contexts.

Relatedly, VR supports investigation into site change. For example, I cross-compare the VR rendition of Site 2 with pictures taken of Site 2 in 2011, offering a real glimpse into how Site 2 has been modified by natural forces and humans over time. This is incredibly useful for researchers trying to understand the effect of global warming and environmental change at a site, for example. However, the technology must be adequate enough to support detailed examination. The cameras used in this experiment, though they picked up on some site change, do not create a clear enough picture to enable deeper site change study.



Figure 57: Photograph of corn cob and other material found at Site 2 in 2011.
Photo taken by author.



Figure 58: 3D photograph of the same location at Site 2 taken in 2026. This 3D image forms the foundation for the VR rendition of Site 2. The blue outline is where the corn cob was located in the 2011 image. Site change is readily witnessed here. 3D photograph taken by Jay Salois from VRtical Media in support of this thesis.

Alternatively, VR offers people an experience of sites from a distance, allowing them to visit places they would never have a chance to go. This VR rendition of Site 2 highlights the potential of VR tourism within a Native American context. My immediate hope is that this type of work can translate to supporting Native American VR tourism for Native Americans, thus allowing for greater access for them to their own sacred sites. As such, programming founded upon VR can potentially be built to serve Native American interests.

One notable limitation: The quality of the VR experience is proportional to the quality of the technology used to capture a site. For this study, a photogrammetry-type photographic technique was used, via the use of high-quality six-lensed 360° camera. But the final product does exhibit a kind of graininess in the image, thereby limiting our capacity to access certain types of detail. As such, this study highlights that the use of a laser-type digital site-capture system, like that used by Palonka and colleagues (2023) at a rock art site in Colorado, may create a rendition with the needed detail to adequately capture and analyze rock art like the rock art on view at Site 2. In other words, the process used to capture the site in this study was sufficient to create a VR digital twin of Site 2, but the sharp detail and contrast needed to study the art within the VR environment is somewhat limited. My belief is that if we had used a laser-enabled site-capture system, we would have garnered more detail. It must be noted that the laser-enabled systems are far more expensive than the photographic systems. Some other notable limitations to VR include: a) where and how to host and access VR files is vital—that is, to do VR right, a researcher must have the appropriate training to not only capture a site, but to also initiate and maintain the webhosting resources, etc.; b) technology in the VR world evolves quickly and keeping up to date with technological changes is also vital; c) there are potential imperfections in a VR rendering of a site which may prevent certain types of archaeological research; d) these imperfections, as mentioned, can be related/proportional to the technology being used—for instance, laser-enabled site-reconstruction, as opposed to photographic reconstruction like that used in this study, will yield greater detail, and this greater detail is vital for the type of detail needed for rock art studies (Palonka et al. 2023); and e) VR is primarily focused on visual aspects of sites, which delimits the types of research that can be performed in a VR environment.

Other considerations with VR: There is a learning curve with actually using a VR headset. It takes a bit of time to get comfortable with the VR headset operations. This is an important detail and it could become a barrier if participants are not comfortable with certain types of technology and/or the practicalities of wearing a VR headset.

As an aside, a secured three-dimensional webpage was generated from the 360° photogrammetry process, and this serves as the visual foundation for the VR environment constructed for Site 2. Interestingly, in several areas the three-dimensional rendition is actually sharper than the final VR version, even though the VR environment is built directly from it. (The secured webpage will be provided to the Thesis Committee for their review.) Beyond its role in the VR experience, this three-dimensional presentation underscores the educational value of producing both three-dimensional and VR representations of rock art sites. It also highlights an important practical point: When VR headsets are unavailable, a three-dimensional presentation can function as a more than adequate alternative.

Lastly, like with the AI techniques seen above, there are real ethical considerations regarding the use of VR with objects of cultural patrimony like sacred sites and sacred images. It may be the case that certain cultures do not want their sites and artworks to be perpetually preserved in a digital format like VR or three-dimensional renderings. In other words, responsible archaeology vis-à-vis VR and three-dimensional work will require that archaeologists research the nuances of tribal perspectives on VR use and photogrammetry in digital preservation activities. It may be that the best archaeological practice is to engage in tribal consultation and collaboration, in as much as is possible, when VR and photogrammetry techniques are being used with sacred rock art images.

Consultation with a Conservator

It was incredibly difficult to gain the perspective of a professional conservator for this thesis. I had high hopes that conservators would want to offer their perspective and expertise and that they would want to help me construct a viable and formal preventive conservation plan. However, I struggled profoundly to engage with conservators. Victoria Clow, who is a well-respected and admired conservator and professor, did offer her insights via an in-depth phone call. This call with Professor Clow was at once thrilling and incredibly interesting. The final analysis of her perspective is as follows:

- 1) She favored passive preservation-type interventions, based on a comprehensive risk assessment, including protecting the artworks and sites from both environmental damage and humans. She sees passive preservation-type interventions as real and successful ways to prevent damage.
- 2) These passive preservation-type interventions, without deeper chemical analysis of the pigments for active repair of the artworks, offer the best and most practical well-rounded preventive conservation and preservation approach. And they can be implemented with little-to-no negative impacts to the sites and at a low cost. These include limiting access to sites, installing barriers and roofing and screening at sites, obscuring sites, placing signage at sites, keeping sites confidential, and more. These are considered to be tried-and-true methods for supporting rock art sites (Zerboni et al 2022).
- 3) It is possible that monitoring can be included in this set of interventions, because cameras can be set up to create a kind of overwatch of these sites. Professor Clow wholeheartedly believes in the preservation power of cameras and their effectiveness, especially at preventing human-caused destruction.

Summary

The multi-methods approach used for this thesis project, though at times dizzying, yields some wonderful and meaningful results. That is to say, all of the data-collection techniques used within this thesis project offered valuable insights and supported the main thesis statement and research questions. Taken together, a multi-methods approach to studying Navajo star ceilings does open the window to new information pertaining to the star ceiling artistic phenomenon, while also proving that certain emerging technologies can be successfully employed to support rock art research.

The pXRF data is incredibly rich in this thesis. It may be thought of as serving as the backbone of the data provided within this work, and more research based on this data is possible. The AI-enhanced digital work, though somewhat simple, aside from Mr. Kashkin's AI model, has important implications both in the digital rock art research realm and in the realm of AI ethics, particularly vis-à-vis archaeology. The VR production of Site 2 is also incredibly rich and meaningful. The potential to use this VR rendition for public archaeology and educational goals is still a real possibility, even beyond the confines of this thesis. Examining the VR rendition of Site 2 for avenues to perform research within the VR environment is also a possibility.

Though the findings of this thesis are exciting, the AI and VR components of this thesis highlight the need for an ethically grounded research design, especially given that Navajo perspectives on the use of these technologies with their sacred images have not yet been articulated. A synthesis of the material presented in this chapter is offered in the Conclusion. This synthesis highlights the particular patterns of interest described in this chapter.

Chapter 7: Conclusion

My approach to investigating this thesis involved performing fieldwork at two distinct Navajo star ceiling sites, one located on private land and the other on BLM public land. This fieldwork centered on several different techniques for data collection. As such, the data-collection work was structured around answering the following research question: How can combining traditional rock art research techniques, such as fieldnotes and photography, together with modern technologies, like pXRF pigment analysis, AI, and VR, provide new insights into the material choices, ritual painting processes, and digital research and preservation of Navajo star ceilings, and what does this reveal about the potential usefulness of emerging digital tools for documenting, conserving, and preserving ancient rock art?

Though broad-ranging, the research for this thesis supported what I call a multi-methods methodology akin to how Carolyn Boyd approaches rock art research in her work with the Pecos River Style artworks located in southwest Texas (Boyd and Cox 2016). The multi-methods approach I employed yielded some important results. When put together, the findings offer insights into both star ceilings and into the multi-methods technique used to gather data. A comprehensive synthesis of the findings is as follows:

Both Site 1 and Site 2 are found in the old Navajo geographical landscape known as the *Diné'tah* (Campbell and Forton 2023). Both are south-facing, and this may suggest seasonal use, or some intentional choice related to maximizing solar energy during cold months and shade in hot summer months (Lightfoot 1994). This south-facing orientation also allows for interpretation about the potential night sky observational/viewing activities by way of each respective site.

Site 1 exhibits features akin to a potential smaller hunting camp site, or smaller ritual site, where artwork was created while the artist was lying on their back. The artwork of the five stars

seen in Site 1, Alcove 2 may be placed in the pattern of a known Navajo constellation; this constellation appears in the night sky in autumn and is prominent throughout the autumn and winter, and into early spring (EarthSky 2025). The artwork here also seems to be associated with a bentonite clay vein, a substance known to have cultural and practical value for the Navajo people (Native Americans Albuquerque Network 2026; Wyman and Harris 1941).

Additionally, Site 1 exhibits a hearth with a mano that contains pollens of wild seeds and other trees endemic to the area around Site 1, yet there is no evidence of corn (Cummings 2025). Some of these seeds are available only during particular times of the year. Sagebrush, for instance, which is found on the mano, seeds in the autumn in New Mexico (BLM 2024).

Site 1 also contains ancient Pueblo-style petroglyphs that predate the pictographic stars (Schaafsma 1963). Site 2 is a much larger site and seems to be amenable to large communal gatherings and large ceremonials. It contains corn and mudballs and other items of note (Christian 2012). Site 2 also exhibits hundreds of pictographs.

The uniformity of star sizes between the two sites points to a possible complementarity among artists on how to produce stars, perhaps suggesting a standard uniform star icon. Perhaps, too, we can see into the minds of the artists here, in that this iconographic template is also a mental image that is carried in the minds of the artists themselves (Bayrak 2025); or, the artworks are an iconographic language and vocabulary, or “semasiography,” communicating ideas through star symbols (Boyd and Busby 2022; Mikulska 2020:9).

Even though there may be uniformity with the icons’ sizes, it is evident that differing techniques were used to apply or paint the pictographs. At Site 1, there is evidence of burnt bone being used to create the five-star pattern, while at Site 2 there is evidence of finger painting and

arrows with stencils to create the pictographs painted on the ceiling, which is 60 feet high at its apex.

Both sites were used repeatedly over the generations, and even across culture groups. There is evidence, deriving from analysis of pXRF data, of *retouche* at Site 1 and the rock art panel adjacent to Site 2 (Cortea 2025; Far Western 2025). Site 2 also shows evidence of human modification of artworks over time with the use of both mudballs and mud (Christian 2012).

Importantly, these sites were revisited, and the revisiting seems to have occurred over long stretches of time. The sites appear to have been held in the collective memory of the peoples and cultures that used the sites and therefore served as some sort of visual archive, or visual language, encoded with deep meaning (Bayrak 2025; Cortea 2025; Far Western 2025).

The mudballs evident at Site 2 were made with mud found in the spring below the artworks contained inside the cave, again based on elemental analysis via pXRF (Far Western 2025). In prior research, a twig extracted from one of the mudballs dated to 1520-1660 AD, meaning the artworks that some of the mudballs cover are older than this time period, understood through this superposition of the materials (Christian 2012). Work performed by the author in the past also suggests that star ceilings and mudballs could be part-and-parcel of ceremonials related to weather magic and ceremonial protection from invading enemies like the Spanish who arrived in the region in the 1500s (Christian 2012). This type of magic and ceremonial protection is witnessed in Navajo mythology like that presented in the Mountain Chant, wherein weather magic based on the creation and ceremonial use of mudballs is used to thwart enemies (Matthews 1997).

Red ochre/hematite and magnetite are iron-based minerals found in the artworks analyzed with pXRF at both sites (Cortea 2025). The choice of red and black seems symbolically

important since it is known that the Navajo can make other dyes and pigment colors (Hollowell 1948). It is possible that this choice of colors is associated with warfare and hunting and ceremonial protection as noted by the author in past research (Christian 2012). In some way, then, we can surmise that red and black were chosen for the pigments for these particular artworks at these particular sites for a particular reason.

The pXRF results indicate that some minerals used in the pigments can be, at some future time, traced back to their source, enabling researchers to relocate where the minerals were mined (Cortea 2025). Also, bone was used in the pigments of a few of the pXRF-sampled pictographs (Cortea 2025). Likewise, modern lead paint was used in a reworking of a large pictograph associated with, and located adjacent to, Site 2 (Cortea 2025; Far Western 2025).

Regarding techniques, the modern technology used in this thesis does support deep analysis of the artworks and assists in both creating new research approaches and conceiving of the artworks in new ways. That is to say, the emerging technology used here can also practicably support new research, conservation, preservation, and educational activities. pXRF, for instance, has shown great results in rock art studies in general and in this thesis as well, though it does have limitations in that the quality of interpretation is proportional to the quality and quantity of the reference data used in the comparative analysis.

The other emerging technologies—AI and VR in particular—are definitely useful techniques and tools for rock art research, though there are some limitations and ethical considerations to keep in mind. Issues of digital stewardship need to be seriously considered when using these technologies (United Nations 2023).

The effect of awe within the VR context is important (Quesnel and Riecke 2018), especially in its capacity to engender greater awareness about issues pertaining to heritage

conservation and preservation (Nascimento and Loureiro 2024). Too, the VR rendition of Site 2 emphasizes VR's ability to support archaeological education; this technique is absolutely amenable to supporting pedagogy in an archaeological context. What's more, the idea of being able to reduce barriers to access to sacred sites for Native American tribal members via VR techniques carries much potential. It is also cost effective, once the individual researcher has obtained the appropriate equipment and learned the technique. That is, VR is replicable and affordable.

Likewise, being able to digitally reconstruct, restore, and record artworks via AI is a useful tool in rock art studies and beyond. AI can also be used to facilitate computational processing for both known and unknown variables in rock art production; in this way, AI can act as an external research support resource.

On the whole, the findings of this thesis align with the notion that AI and VR augment archaeological fieldwork and traditional recordation and analysis activities, especially when used with ancient rock art. Though, with respect to VR, the quality and type of VR site-recording technology is crucial; that is, this research highlights that a photographically grounded site-capture method can limit detail of rock art, and it may be that a laser-enabled site reconstruction method is more suited for site capture.

In the last analysis, these tools are inherently non-destructive and can be harnessed to help with conservation and preservation as well. And they can assist in stretching our ideas about how to approach research design vis-à-vis rock art studies. In some sense, then, these technologies contain the ability to open new, heretofore unknown, pathways for recordation and elucidation and education.

Limitations

The limitations for this research fall within two categories: 1) limitations regarding my overall approach; and 2) limitations regarding the individual data-collection techniques.

Regarding the limitations of my overall approach: Though applying a multi-methods approach to comprehending star ceilings has yielded some wonderful results, it can be seen as too far-ranging and somewhat scattered. That is to say, this type of methodology necessitates remaining absolutely focused—with an especially keen eye—on the thesis research question throughout. In addition, because of its vulnerability to becoming scattered, or being too broad, this approach could be seen as naïve and therefore could appear hobby-ish or gimmicky. Given that the findings support the thesis statement, and this approach is replicable, the proof is in the results. This multi-methods approach does work.

But the vulnerability to criticism of this type of multi-methods approach could hinder future research along these lines. It may be more beneficial in the future to sculpt the various data-collection methods in a way that is more focused. Admittedly, this specific limitation is rooted in the author's excitement about the research topic itself, as well as the excitement of employing new and emerging technologies to examine rock art.

There are limitations to the specific data-collection techniques employed: As mentioned in the Analysis chapter, one important limitation for the use of pXRF is the fact that the quality and breadth of the data interpretation is based on the experience of the XRF analyst and the database used to compare the spectral data. This means that researchers can have varying results and analysis based on the limitations and/or robustness of the spectral data used to compare the pXRF scans.

In addition, the main limitations for using AI in this type of research, as mentioned, are centered around the ethics of using AI for the analysis of sacred images. This brings to the fore the absolute crucialness of considering digital stewardship and issues of sovereignty when using AI for archaeological research, especially with rock art. Also, AI is not a perfect system and it can't solve all scientific problems, so responsible use of AI—acknowledging its inherent dangers and limitations—is vital. In other words, AI is not a digital savior; rather, it is a tool, or a kind of assistant, that can be harnessed to manipulate images and ideas vis-a-vis studying rock art.

The limitations for VR coalesce around the actual machines used to digitally capture sites and the programming used to create the VR environments. In this respect, the better the technology, the better the virtual rendering of a site. What I have found through this research project is that rock art studies, in and of themselves, necessitate greater detail. Though I was astounded by the VR rendition of Site 2, and it has definite research value, there remains a kind of graininess to some of the pictographs. In the end, the more money invested in better VR equipment the better the research potential. This fact will drive some costs of VR upward, but it's still relatively lower in cost than artifact storage in perpetuity.

In the examination of the mano, I was unable to actually temporally locate the seed-grinding activity with the star pictographs contained at Site 1. Grinding and seed processing took place at Site 1, but we don't actually know if it took place at the same time as the making of the artworks. I simply ran out of funding and couldn't contract for radiocarbon dating of the charcoal found in the vicinity of the artworks at Site 1.

Similarly, this study suffers from a lack of contemporary Navajo perspectives on the work done here and the Navajo perspectives on the research design, interpretation, and preservation value of the results. Therefore, the interpretation of the results, though grounded in

my attempt at ethically-principled research activity, in the spirit of Colwell-Chanthaphonh and Ferguson (2004), are inherently limited not only because living Navajo voices are not represented but also because I am not a Navajo tribal member. I did gather some informal perspectives on the star ceilings themselves and some of the material found at these sites, but I could not formally engage with Navajo tribal experts on my methodology and my results and interpretation. This was not from a lack of trying. I did attempt to bring more Navajo voices into this work but was unable to do so. Frankly, I believe this outcome reflects two intersecting forces. First, the thesis timeline did not allow for the development of the kind of trust-based relationships with Navajo community members that the collaborative work I wanted to do requires. Second, I recognize that the topic itself may have created discomfort for some Navajo individuals, both because of my status as a non-Navajo researcher and because certain aspects of star ceiling rock art may be too culturally sensitive. Indeed, this fact fueled my conflict about whether or not I should be studying these sacred artworks at all.

Lastly, I was also unable to truly gain a meaningful foothold within the conservators' world. Professor Victoria Clow graciously took time to consult with me, and that was fruitful; but I was unable to gain another's perspective on potential conservation techniques, especially those related to chemical-type conservation. I had originally hoped that, based on the pXRF data, we could build a legitimate conservation plan that included active interventions, like chemical appliques and the like, not to be deployed at the sites, but to have as a record for future rock art researchers. My sense is that their professional code of ethics does not allow them to speak on conservation issues that lie outside of their own expertise. This gap is a notable missing piece for me in this thesis research.

Suggestions for Further Research

First and foremost, relocating where the pigments that were used to create the pictographs were mined is possible and will make for a fascinating research project. Relatedly, examining how these mines are geographically positioned, particularly with respect to each star ceiling site, will offer more clues about the process that undergirds the literal making of star ceilings. Performing a landscape study of star ceiling icons, from those found in the old traditional Navajo homeland, the *Dinéetah*, to the current Navajo Reservation, will offer insights into potential iconographic changes over time. Also, given the small number of pXRF-analyzed pictographs, it will be worthwhile to perform XRF scans on yet more star ceiling pictographs in the effort to build a larger compendium of XRF data pertaining to star ceiling sites. Given that only two sites were researched for this thesis, examining more sites using a multi-methods approach may support increasing our understanding of star ceilings and their role in Navajo culture and history.

Research into icon form as it relates to star ceiling pictographs should yield some interesting insights. Together with this, a compelling research topic grounded on the periodic revisiting and retouching of certain pictographs will provide some interesting perspectives on the importance of rock art. This behavior speaks to the power of these sites to bring people back to tend to them in some way, by repainting the art. Also, research into iconographic language, or semasiography, and how it may be witnessed in ancient rock art is fascinating and will provide very interesting pathways for understanding the various meanings of star ceilings.

Importantly, especially as AI becomes increasingly utilized in a myriad of professions, including archaeology, diving into ethical use of AI and further defining ethical use for archaeology and rock art studies in particular will be crucial. How these ethics interface with Native American cultures will also need to be a principal motivation for archaeologists and rock

art researchers working with sacred images and objects. It is recommended that a real code of ethics for AI use with rock art studies be developed and launched.

The AI reconstruction techniques explored in this thesis are simple, but they offer a doorway into new ways of thinking about digital reconstruction, restoration, and conservation. Moving deeper into the AI digital reconstruction techniques will perhaps be an important tool for future archaeologists and archaeological educators. Again, ethical use of AI will need to form the foundation of these activities moving forward.

As mentioned, the VR aspects of this project were profound for me. Gaining more expertise in this technique, I argue, will help archaeology in the long run. For instance, examining what types of archaeological research can actually be performed in a VR rendition of a site and how will offer a new frontier for digital archaeology. Together with this, exploring VR and its ability to support education, preservation, and conservation will also be a fruitful line of inquiry. My sense is that there are barriers to this technology and perhaps examining what these barriers are and how to reduce them, so that professionals and students gain comfort and expertise in this technology, has a great deal of potential for archaeology and rock art studies.

Psychological studies on VR in the archaeological context point out the effect of awe on participants. Pursuing lines of inquiry pertaining to awe in the VR context is incredibly interesting, and it may be possible to begin to structure preservation and conservation programming based on the motivational power of awe in VR. That is, we can harness the power of awe in VR to expand educational and preservation goals. We can also perform general psychological assessments related to the phenomenon of awe in VR and the presumed positive effects on mental health and well-being.

To repeat and to emphasize the point, in terms of utilizing novel techniques like AI and VR with Navajo star ceilings, this thesis work emphasizes that future research using these techniques needs to be utilized by way of an adequate ethical framework; that is, ethical frameworks need to be researched, developed, articulated, and implemented that address issues cultural patrimony and of tribal sovereignty especially vis-à-vis AI and VR technologies. This thesis does not take as its primary aim the philosophical investigation of the morality and ethics surrounding the use of AI and VR in archaeological work, but it does highlight the necessity—especially as society is now being confronted with the proliferation of AI—of seriously considering how archaeological investigation responsibly moves forward as the use of these technologies becomes increasingly available and increasingly normalized. Much more research can be performed along these lines, and it needs to begin now.

Last, there is evidence that the cross-shaped star motif transcends culture groups. Investigating the trans-cultural and trans-geographical characteristics of this equilateral cross-shaped star motif may unveil something of its hidden value and meaning. For instance, an extremely sacred object of the Skidi band of the Pawnee people, known as the Skidi Pawnee Chart of the Heavens, now held at the Field Museum in Chicago, contains scores of equilateral crosses that represent the stars of the night sky (Figure 59). How is it that this icon has such sticking power in the minds of people? In what ways has it moved through space and time and cultures?

According to the well-known Archaeoastronomer, Von Del Chamberlain:

We see that the Skidi [Pawnee] based their lives on observations of the heavens. From such observations they judged their origins, determined their calendar and managed time,

and derived principles of leadership and community. Their celestial orientation helped them feel secure either out on the vast prairie or within their homes that were microcosms of the greater world around them. (1982:276)

Any research to better understand this simple and beautiful star motif is a work to understand our universal yearning for connection to the stars of the night sky!

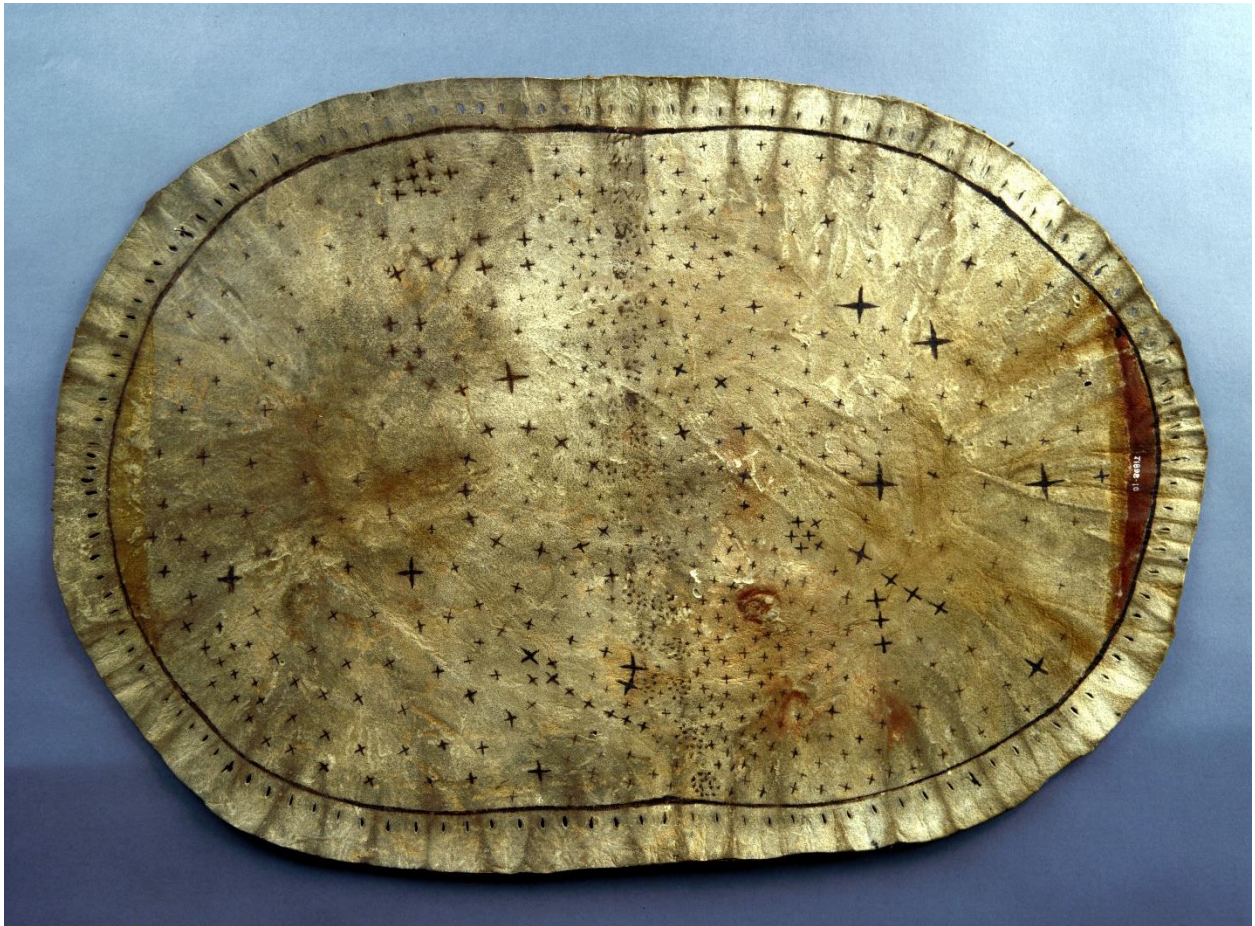


Figure 59: Star Map, The Skidi Pawnee buckskin Chart of the Heavens. It is said the size of a star on the skin depends not only on its brightness in the sky, but also on its assumed power
© The Field Museum, Image No. CSA16231c, Cat. No. 71898, Photographer Ron Testa.
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Appendix 1: Archaeological Site Summary for Site 2

Report run on: Sep 02, 2025 12:20 PM

Archaeological Site Summary

LA No. 109030

Site Status: Available for public query

Site Details

Site Name(s): Ojo Jarido
Other Site No(s): 125012, NM-017-26907
Owner/Manager: US Bureau of Land Management Albq. Dist.-Rio Puerco Resource Area
Occupation Type: Both Historic and Prehistoric
Linked Activities: 48922, 155465

Site Visits

Visit Number:	1
Recording Agency:	US Bureau of Land Management Albq. Dist.-Rio Puerco Resource Area
Recording Date:	13-Apr-1994
Field Site Number:	
Accessibility:	Accessible
Visibility (%):	76-99%
Recording Activities:	Sketch Mapping, Photography, Shovel or Trowel Tests; Probes, In-field Artifact Analysis
Surface Collection:	No Surface Collection
Archaeological Status:	
Disturbance Sources:	Wind Erosion, Water Erosion, Bioturbation
Details of Vandalism:	
Site Intact (%):	51-75%
Observation on Site Condition:	Unauthorized surface collections
ARMS Comments:	

Visit Number:	2
Recording Agency:	US Bureau of Land Management Rio Puerco Field Office
Recording Date:	24-Aug-2007
Field Site Number:	
Accessibility:	Accessible
Visibility (%):	Unknown
Recording Activities:	Other: Site condition assessment
Surface Collection:	No Surface Collection
Archaeological Status:	
Disturbance Sources:	Historic ranching and homestead activities. Modern tourists
Details of Vandalism:	
Site Intact (%):	76-99%
Observation on Site Condition:	Despite disturbances, the site is in much the same condition as previously recorded
ARMS Comments:	There are archaic sites on the mesa above and archaic deposits may exist under more recent deposits

Archaeological Site Summary

LA No. 109030

Site Status: Available for public query

Site Visits (continued)

Visit Number:	3 NMCRI No. 155465
Recording Agency:	University of New Mexico Maxwell Museum
Recording Date:	
Field Site Number:	125012
Accessibility:	
Visibility (%):	
Recording Activities:	
Surface Collection:	
Archaeological Status:	
Disturbance Sources:	
Details of Vandalism:	
Site Intact (%):	
Observation on Site	
Condition:	
ARMS Comments:	

Location

Source Graphics: USGS 7.5' Topo Maps

UTM Coordinates:

USGS Quad:

Physical Description

Type text here

Site Dimensions: 120 x 100 m (Estimated), 1200 sq m (Estimated)

Elevation: 7080 feet

Boundaries: Yes

Complete?:

Depositional / Alluvial, Aeolian, Colluvial

Erosional

Environment:

Stratigraphy: Subsurface Deposits Present

Estimated Depth: .45m

Depth Basis: Shovel/Trowel Tests, Road or Arroyo Cuts

Subsurface

Observations:

Topography: Base of Cliff, Flood Plain/Valley, Rockshelter, Talus Slope

Assemblage

Archaeological Site Summary

LA No. 109030**Site Status: Available for public query**

Assemblage (continued)

Assemblage: Lithic Debitage, Chipped-stone Tools, Diagnostic Projectile Points, Diagnostic Ceramics, Other Prehistoric Ceramics, Diagnostic Glass Artifacts, Other Glass Artifacts, Diagnostic Metal Artifacts, Other Metal Artifacts, Diagnostic Ceramics, Other Historic Ceramics, Macrobotanical Remains, Architectural Stone

Assemblage Size:

Lithic artifacts:	10s
Ceramic artifacts:	10s
Historic artifacts:	10s
Total artifacts:	100s

ARMS Assemblage Summary: Dineta Gray, Chaco B/W, Gallina utility ware, and corrugated ceramics

Cultural / Temporal Affiliations

Component:	1 of 4
Cultural Affiliation:	Anasazi
Temporal Basis:	Associated Diagnostic Artifact or Feature Types
Period(s):	Pueblo III (1100 AD) to Pueblo III (1200 AD)
Dating Status:	Relative Techniques
Component Type:	Artifact scatter
Remarks:	
Phase(s):	Gallina / Largo-Gallina
Component:	2 of 4
Cultural Affiliation:	Anasazi
Temporal Basis:	Analytically Derived Assemblage Data or Archaeological Experience
Period(s):	Pueblo III (1100 AD) to Pueblo III (1300 AD)
Dating Status:	Relative Techniques
Component Type:	Artifact scatter
Remarks:	
Phase(s):	
Component:	3 of 4
Cultural Affiliation:	Navajo
Temporal Basis:	Associated Diagnostic Artifact or Feature Types
Period(s):	Pre-Pueblo Revolt (1550 AD) to Pre-Pueblo Revolt (1692 AD)
Dating Status:	Relative Techniques
Component Type:	Artifact scatter
Remarks:	
Phase(s):	

Archaeological Site Summary

LA No. 109030**Site Status: Available for public query**

Cultural / Temporal Affiliations (continued)

Component:	4 of 4
Cultural Affiliation:	Anglo
Temporal Basis:	Analytically Derived Assemblage Data or Archaeological Experience
Period(s):	NM Statehood - WWII (1912 AD) to NM Statehood - WWII (1945 AD)
Dating Status:	Relative Techniques, Other: GLO survey map
Component Type:	Single residence
Remarks:	
Phase(s):	

Features

Feature Type:	House Extant
Number Observed:	1
Feature ID, Notes:	Str. 1; Single room stone house
Feature Type:	Structure Extant
Number Observed:	1
Feature ID, Notes:	Str. 2; Small stone building
Feature Type:	Rockshelter
Number Observed:	1
Feature ID, Notes:	Sheep dung build-up

ARMS Feature**Remarks:****General Site****Comments:**

Eligibility Statements / Determinations

Associated NMCRIS No: N.R. Listed: ☐ HPD Log No: 47834 Edited:	Eligibility Criteria: ☐ A ☐ B ☐ C ☒ D ☐ MPL State Reg. No: Formal Determination: ☐
Associated NMCRIS No: N.R. Listed: ☐ HPD Log No: 47834 Edited:	Eligibility Criteria: ☐ A ☐ B ☐ C ☐ D ☐ MPL State Reg. No: Formal Determination: ☐
Associated NMCRIS No: N.R. Listed: ☐	Eligibility Criteria: ☐ A ☐ B ☐ C ☒ D ☐ MPL State Reg. No:

Archaeological Site Summary

LA No. 109030

Site Status: Available for public query

Eligibility Statements / Determinations (continued)

HPD Log No:	Formal Determination:	☐
Edited:		
Associated NMCRIS No:	Eligibility Criteria:	☐ A ☐ B ☐ C ☐ D ☐ MPL
N.R. Listed:	State Reg. No:	☐
HPD Log No:	Formal Determination:	☐
Edited:		
Associated NMCRIS No:	Eligibility Criteria:	☐ A ☐ B ☐ C ☐ D ☐ MPL
N.R. Listed:	State Reg. No:	☐
HPD Log No:	Formal Determination:	☐
Edited:		
Associated NMCRIS No:	Eligibility Criteria:	☐ A ☐ B ☐ C ☐ D ☐ MPL
N.R. Listed:	State Reg. No:	☐
HPD Log No: 47834	Formal Determination:	☐
Edited:		

Appendix 2: ARPA Permit for Site 2



United States Department of the Interior

BUREAU OF LAND MANAGEMENT
New Mexico State Office
301 Dinosaur Trail
Santa Fe, New Mexico 87508
<https://www.blm.gov/new-mexico>



8/29/2025

In Reply Refer To:
8100 (9300)

Thomas Christian
University of Maryland
4302 Chapel Lane
College Park, MD 20742

Dear Permittee:

Enclosed please find Cultural Resource Use Permit, #389-2920-25-A, which authorizes your firm to conduct work on public lands administered by the New Mexico Bureau of Land Management (BLM).

Please note this permit is authorized under the authority of the Federal Land Policy and Management Act (FLPMA), and not under the Archaeological Resource Protection Act (ARPA). This permit only authorizes Survey and Recordation activities. Shovel testing and other ground disturbing activities may require additional submission of an ARPA permit application.

All field projects carried out under this permit will need to be staffed by a Field Supervisor and Project Director authorized to conduct fieldwork in the appropriate permit area. The permit chart, attached, lists personnel approved under your permit by their role and permit area. Please comply with all stipulations attached to this permit, and requirements in our handbook, "Procedures for Performing Cultural Resource Fieldwork on Public Lands in the Area of New Mexico BLM Responsibilities." This BLM Manual Supplement H-8100-1 is available by emailing a request to blm_nm_cultural_resource_permits@blm.gov.

Please review this manual. It contains guidance for conducting fieldwork: for reports, collections, and documentation preparation and submission, and outlines permit stipulations and the procedures that BLM will follow to ensure that cultural resource fieldwork carried out in New Mexico's area of responsibilities meets our professional standards. **In addition note that this handbook includes a section on "Releasing Report Contents to General Public and/or Private Project Sponsors (page 1-22)." It addresses the guidelines regarding the release of site location information.**

Your permit will expire on 08/28/2026. You may apply for renewal through a simple letter of interest if no essential conditions have changed, or you may submit an Application for Cultural Resource Use Permit. If you need to change any essential conditions, including staff

(adding staff or changing their roles and responsibilities), contact information such as address and telephone, or business name, please use a Request for Modification of Cultural Resource Use form. You may apply to change essential conditions of your permit at any time. Application and modification forms are available online at:

<https://www.blm.gov/programs/cultural-heritage-and-paleontology/archaeology/what-we-manage/new-mexico>

Thank you for your interest in working on our public lands. If you have any questions regarding this correspondence, please contact Sean I Daugherty, Archaeologist, Cultural Resource Use Permit Administrator, New Mexico Bureau of Land Management, at (505) 761-8702 or blm_nm_cultural_resource_permits@blm.gov.

Sincerely,

TOKEY BOSWELL

Digitally signed by TOKEY
BOSWELL
Date: 2025.08.29 09:11:47 -06'00'

Tokey Boswell
Deputy State Director
Division of Lands and Resources

2 Enclosures:

1. Permit # 389-2920-25-A
2. Permit Area Chart of Personnel

**UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
CULTURAL RESOURCE USE PERMIT**

Sec. 302(b) P.L. 94-579, October 21, 1976, 43 U.S.C. 1732 and
Sec. 4 P.L. 96-95, October 31, 1979, 16 U.S.C. 470cc

1. Name of Permittee:
Thomas M. Christian

2. Mailing Address:
4302 Chapel Lane
Collage Park, MD 20742

3. Telephone Number: 254-366-5342

Fax Number:

4. Nature of Authorized Activity:

Survey and recordation

5. Location of Authorized Activity:

a. Legal description or geographic area:

See Attached Chart

b. Identification of cultural resource: Various

6. New Permit Number: 389-2920-25-A

7. Effective Date: 8-29-2025

8. Expiration Date: 8-28-2026

9. Name(s) of individual(s) responsible for carrying out field projects (**Field Supervisors**) in accordance with NM BLM Manual H-8100-1 (listed by Permit Area):

See List

10. Name(s) of individual(s) responsible for planning, supervising, and overseeing field projects (**Project Director**) in accordance with NM BLM Manual H-8100-1 (listed by Permit Area):

See List

11. Name(s) of individual(s) responsible for carrying out the terms and conditions of the permit (**Permit Administrator**) in accordance with NM BLM Manual H-8100-1:

Matthew Palus

TOKEY BOSWELL

Digitally signed by TOKEY BOSWELL
Date: 2025.08.29 09:12:21 -06'00'

APPROVED: _____

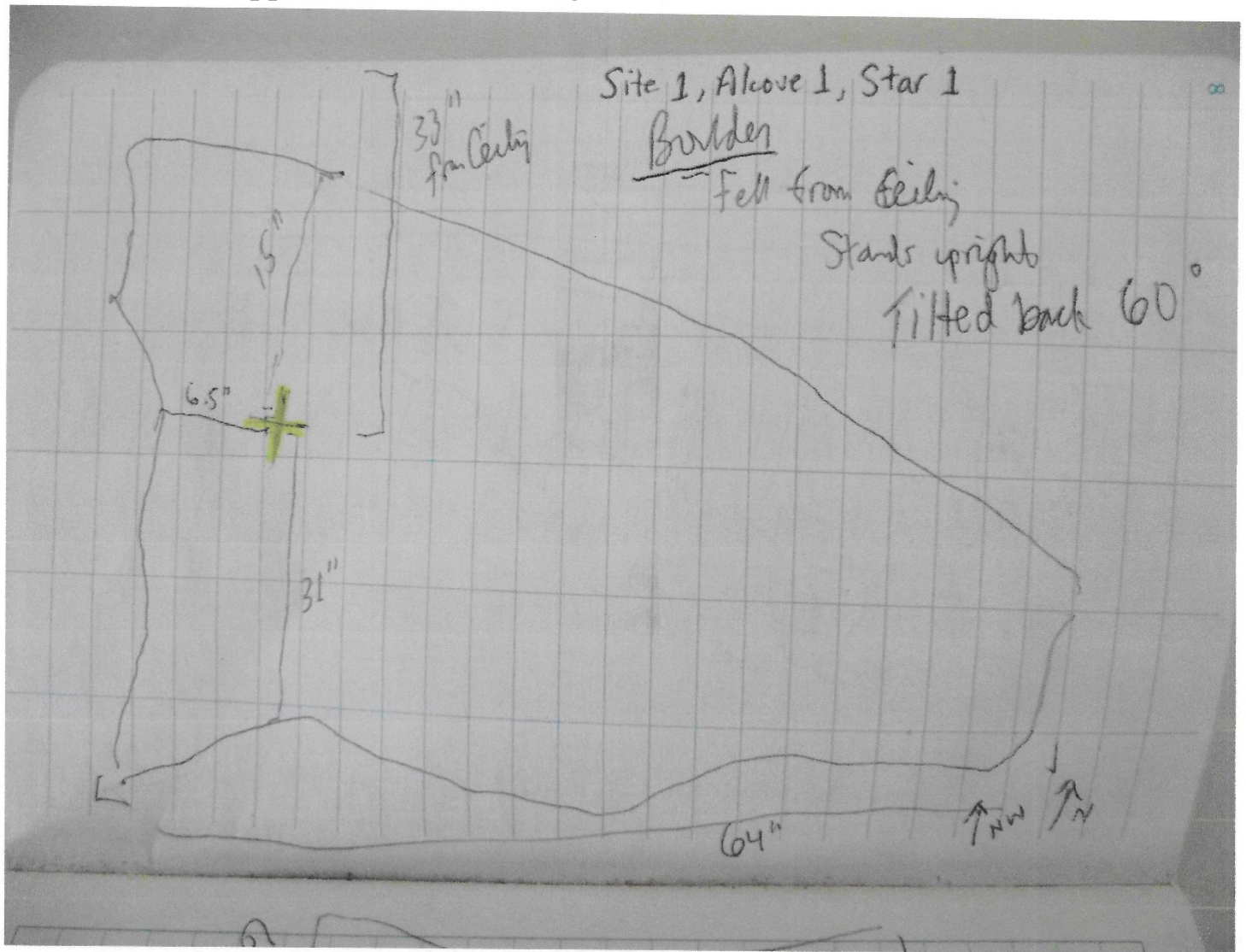
Date: _____

Deputy State Director,
Division of Lands and Resources

PERMIT STIPULATIONS

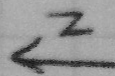
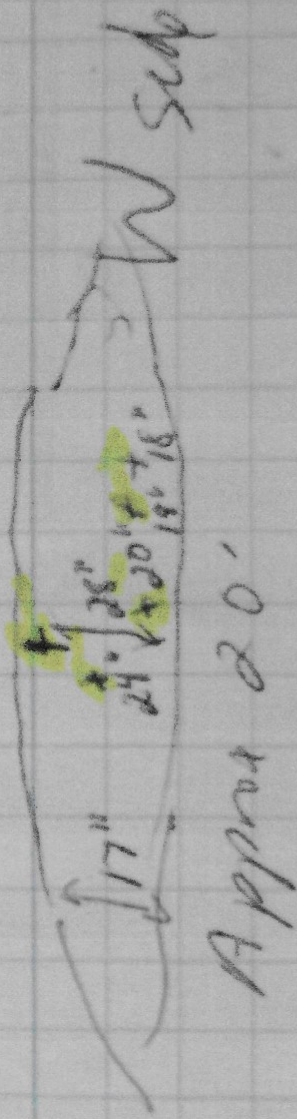
1. This permit is subject to all applicable provisions of pertinent regulation (43 CFR 2920; 43 CFR Part 7) which govern the use of this permit.
2. This permit may not be assigned.
3. Permittee shall immediately request the State Director to make a modification to accommodate any change in an essential condition of the permit (e.g., 5, 8, 9, 10, 11, above), and shall notify the State Director of any other changes, affecting the permit or regarding information submitted as part of the application for the permit, without delay. Failure to do so may result in permit suspension or revocation.
4. This permit is issued for the period specified. It is subject to suspension or revocation, for management purposes or for cause, at the discretion of the State Director, upon written notice.
5. Permittee may request permit extension, in writing, at any time prior to expiration of the term of the permit, specifying a limited, definite amount of time required to complete permitted work.
6. Permittee shall observe all Federal, State, and local laws and regulations applicable to the public lands and resources.
7. Any correspondence about this permit or work conducted under its authority must cite the permit number. Any publication of results of work conducted under the authority of this permit must cite both the Bureau of Land Management and the permit number.
8. Special conditions attached to this permit are made a part hereof.
9. Permittee shall contact the Manager of the affected Field Office prior to beginning any field work involving survey (2920) or Archaeological Resources Protection Act (ARPA) Data Collecting (Limited testing or excavation) projects under 8152 permits.
10. Permittee shall submit an annual report on cultural resource fieldwork on public lands administered by New Mexico BLM each year. These reports shall be submitted to the State Office by December 1; reports shall follow the format suggested in the attached description.
11. Permittee shall comply with all stipulations enumerated in Handbook H-8100-1, Procedures for Performing Cultural Resource Fieldwork on Public Lands in the Area of New Mexico BLM Responsibilities.

Appendix 3: Archaeological Field Notes of Sites 1 and 2

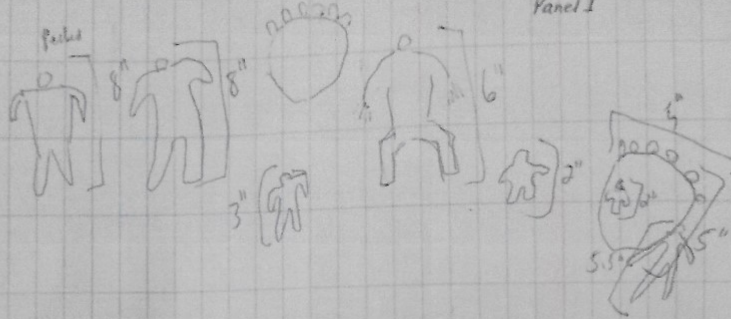


W
Apex. 100'

Site 1, Alcove 2, 5 Stars



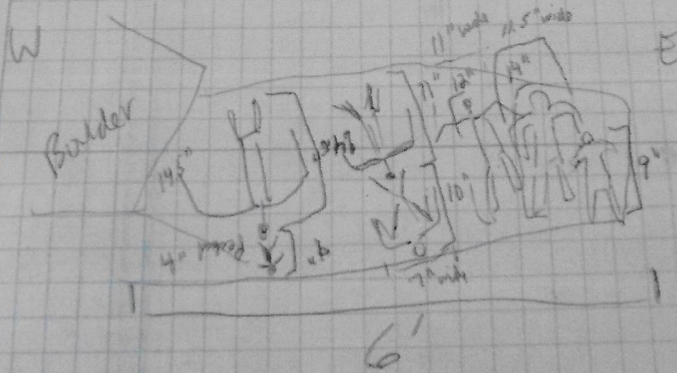
Site 1, Alcove 1, Petroglyphs
Panel 1

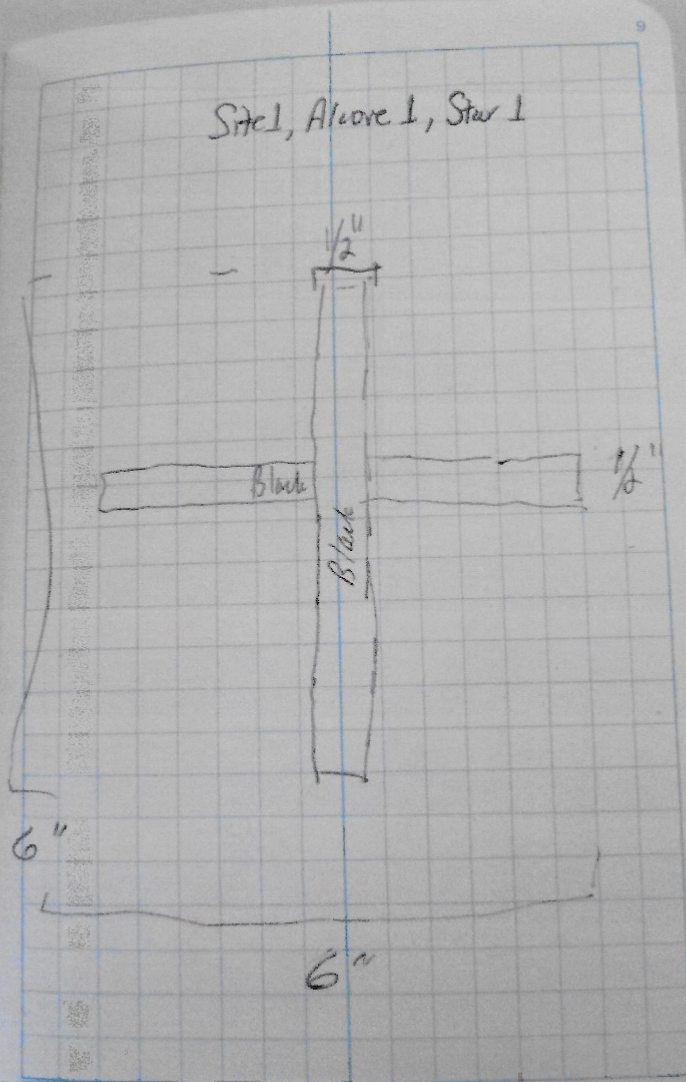
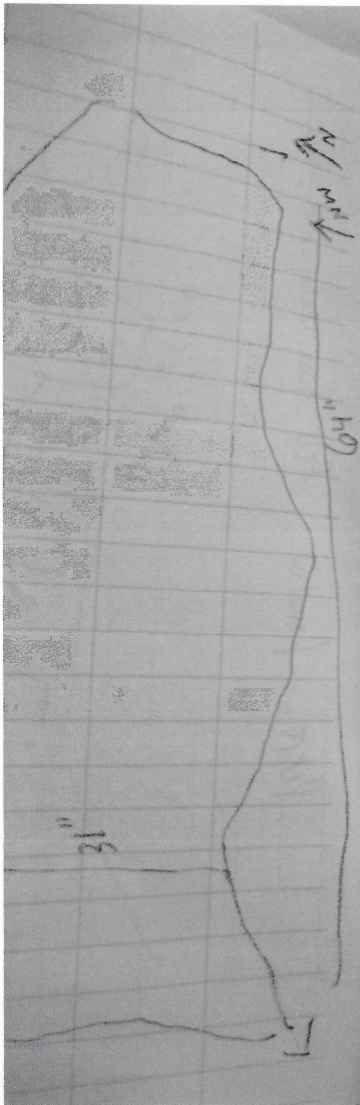


East Side 4.5' in length

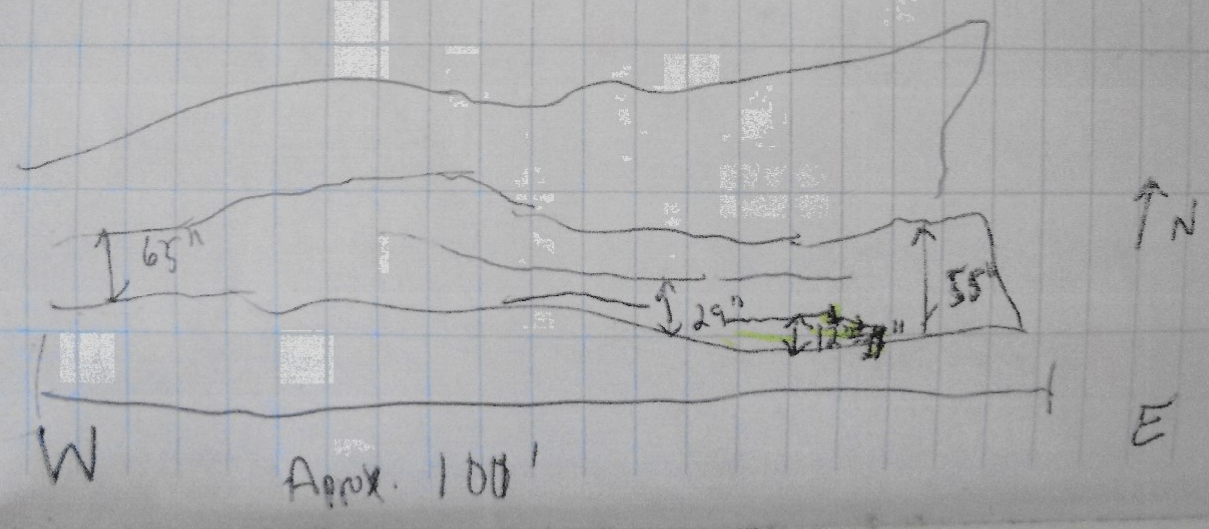
9 petroglyphs discernable

Petro Panel 2 fell from ceiling/back wall

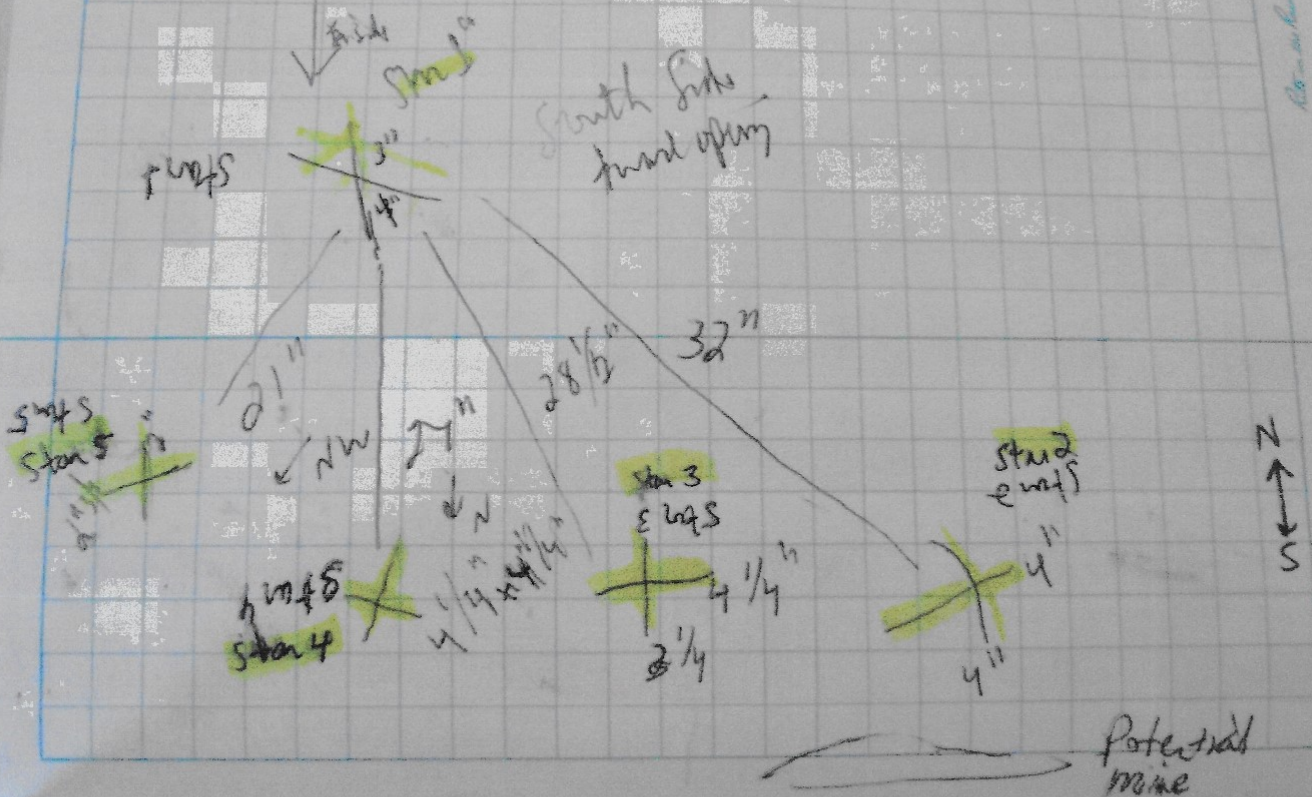




Site 1, Alcove 2, Stars and bentonite clay interior



Outside looking into Site 1, Alcor 2, 5 stars



OJO JARIDO

Site 2

Stn 1 →

6870 ft

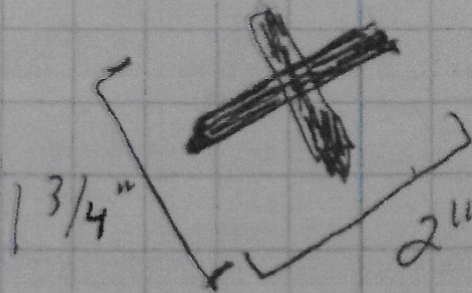
35° 54.340'

w 107.03,661'

4' from interior

4' tall

Red



Stn #1

030 Shilo, Site 2

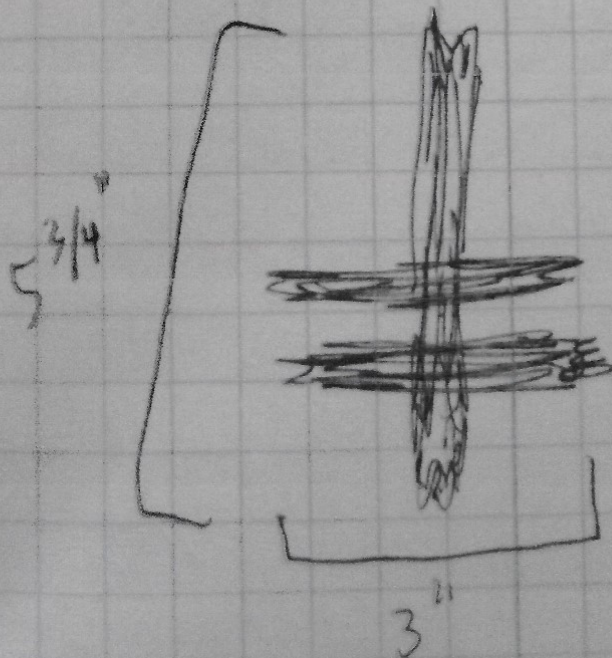
Stn #2 080 Tando

6661 ft

N $35^{\circ} 54.368'$

W $107^{\circ} 03.597'$

6' [±] off ground



Site 2

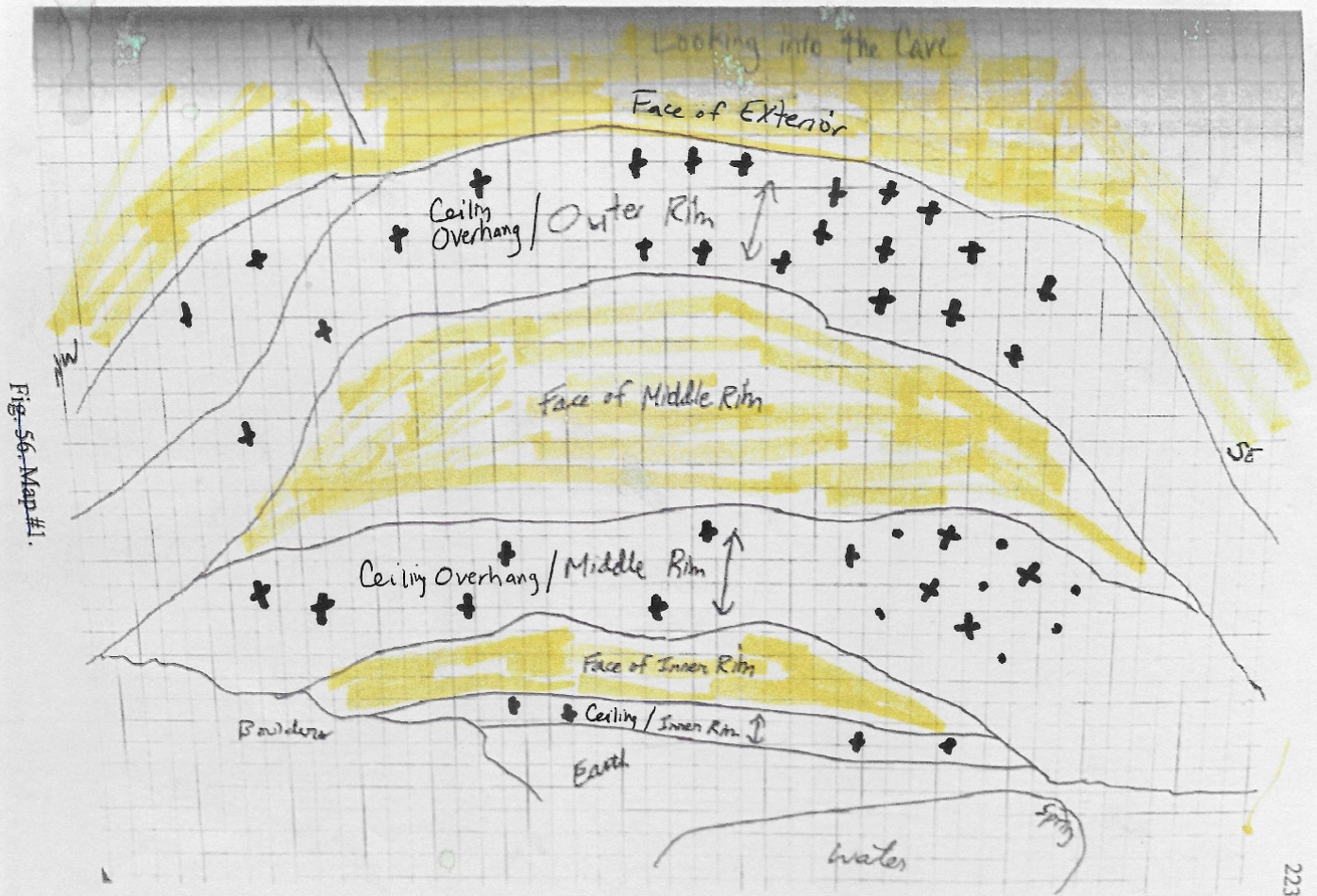


Fig. 56-Map #1.

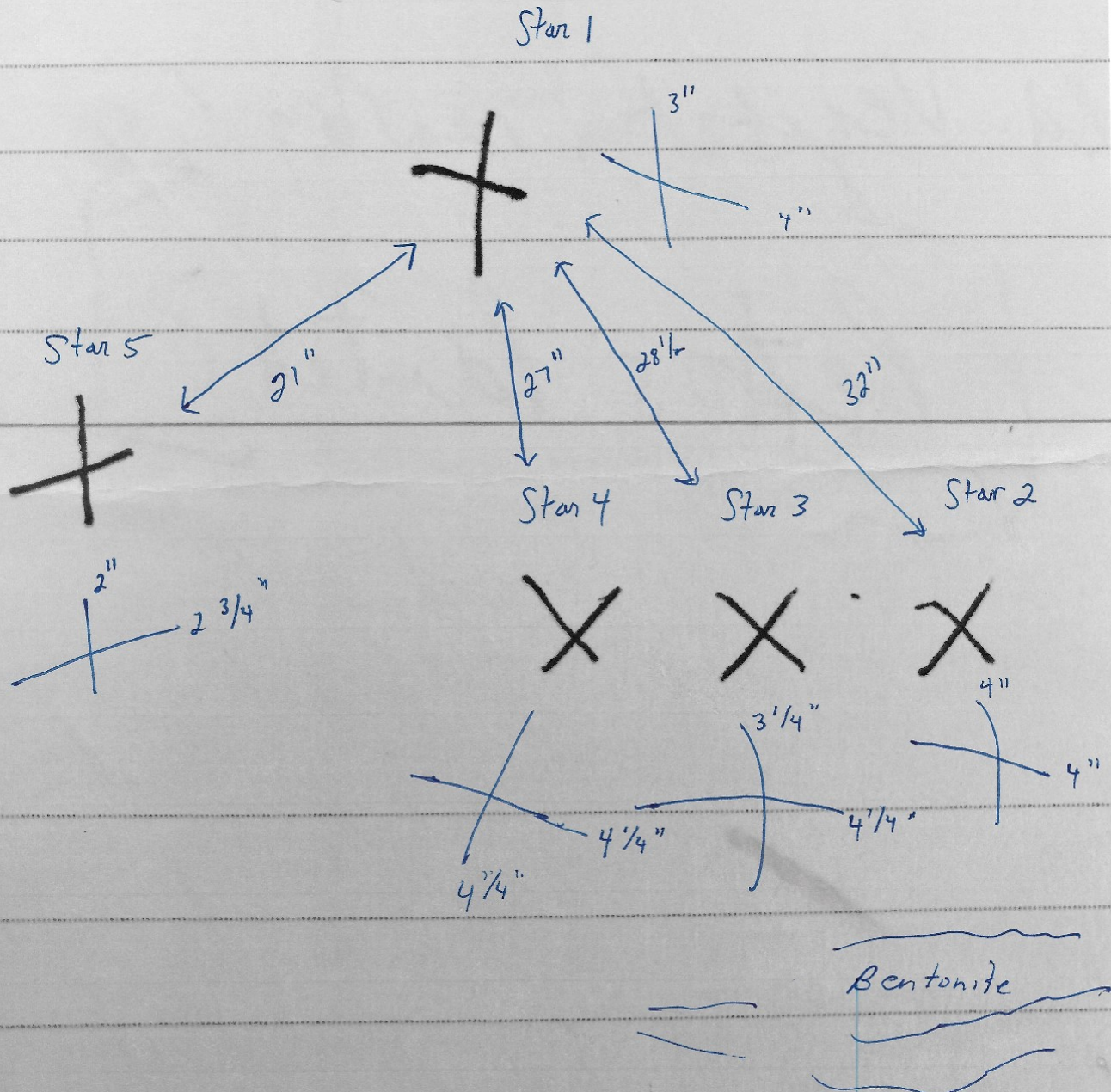
223

162 Rock face

+ Overhang ceiling w/ Art
• Mudball "offerings"

Site 1 Alcove 2

Shelter ceiling is approximately 2 feet high
 Looking up from laying down on ground
 Head facing out of shelter mouth (south)
 Feet inside shelter (north)



Appendix 4: Mano Analysis for Site 1

POLLEN ANALYSIS OF A MANO FROM A ROCKSHELTER IN NORTHWESTERN NEW MEXICO

BY

LINDA SCOTT CUMMINGS

With assistance from

R.A. Varney

PaleoResearch Institute

Golden, Colorado

PaleoResearch Institute Technical Report 25-019

Prepared for

Tom Christian

December 2025

METHODS

Groundstone Washes for Pollen and Starch

Use of groundstone in processing plants and animals may leave evidence on the artifact surface that includes concentrations of pollen and starch, which can be recovered by washing the ground surfaces.

First, all visible dirt was removed using tap water and gentle hand pressure to remove any modern contaminants. A small portion of each ground surface was tested with dilute (10%) hydrochloric acid (HCl) to detect the presence of any calcium carbonates. If present, these carbonates were removed with additional dilute HCl. Then, the ground surfaces were washed with a 0.5% Triton X-100 solution to recover any pollen and starch grains. The surface was scrubbed with an ultrasonic toothbrush and rinsed thoroughly with reverse osmosis deionized (RODI) water. Each sample then was sieved through 250-micron mesh to eliminate any large particles that might have been released during the washing process. The pollen and starch samples were then freeze-dried using a vacuum line.

Once dry, the samples were mixed with sodium polytungstate (SPT), at a density of 1.8 g/ml, and centrifuged to separate the organic material including pollen and starch, which will float, from the inorganic remains and silica, which will not. The supernatant containing pollen and organic remains was decanted. Sodium polytungstate was added a second time to the inorganic fraction to repeat the separation process. The supernatant was decanted into the same tube as the supernatant from the first separation. This supernatant then was centrifuged at 1,500 rpm for 10 minutes to allow any remaining silica to be separated from the organics. Following this, the supernatant was decanted into a 50-ml conical tube and diluted with reverse osmosis deionized (RODI) water. These samples were centrifuged at 3,000 rpm to concentrate the organic fraction in the bottom of the tube. This pollen-rich organic fraction was rinsed and then received a short (25 minute) treatment in hot hydrofluoric acid to remove any remaining inorganic particles. The sample was acetylated for 10 minutes to remove extraneous organic matter. The sample was rinsed with RODI to neutral. Following this a few drops of potassium hydroxide (KOH) were added to the sample which was then stained lightly with safranin. Due to the presence of large quantities of minute organic debris, the sample was centrifuged at high speeds for short intervals to remove this debris for better viewing.

A light microscope was used to count the pollen at a magnification of 500x. Pollen preservation in these samples varied from good to poor. Comparative reference material collected at the Intermountain Herbarium at Utah State University and the University of Colorado Herbarium was used to identify the pollen to the family, genus, and species level, where possible.

Pollen analysis also included observation and recording starch granules and, if they were present, their assignment to general categories. We did not, however, search for starches outside the pollen count. An additional search for starches is performed only when starch analysis is part of the suite of analyses performed. Starch granules are a plant's mechanism for storing carbohydrates. Starches are found in numerous seeds, as well as in starchy roots and tubers. Primary categories of starches include the following: with or without visible hila, hilum centric or eccentric, hila patterns (dot, cracked, elongated), and shape of starch (angular, ellipse, circular, or lenticular). Some of these starch categories are typical of specific plants, while others are more common and tend to occur in many different types of plants.

The pollen diagram was produced using Tilia 2.0 and TGView 2.0.2. Total pollen concentrations were calculated in Tilia using the measurement of the ground/use surface washed in cm^2 , the quantity of exotics (spores) added to the sample, the quantity of exotics counted, and the total pollen counted and expressed as pollen per cm^2 of use surface.

DISCUSSION AND RESULTS

The pollen signature from the mano yielded a very limited record including *Juniperus*, *Pinus*, and *Quercus* pollen (Figure 1, Table 1) representing juniper, pinion pine, and oak trees growing near the shelter. Recovery of small to moderately small quantities of *Amaranthaceae*, *Artemisia*, Low-spine *Asteraceae*, High-spine *Asteraceae*, and a larger frequency of *Poaceae* pollen represent local plants including members of the goosefoot family, sagebrush, ragweed and similar plants, other members of the sunflower family, and grasses. This pollen record suggests grinding grass seeds using this mano. A scan of the microscope slide revealed no *Zea mays* pollen and no starch. A very low total pollen concentration was noted in this pollen wash.

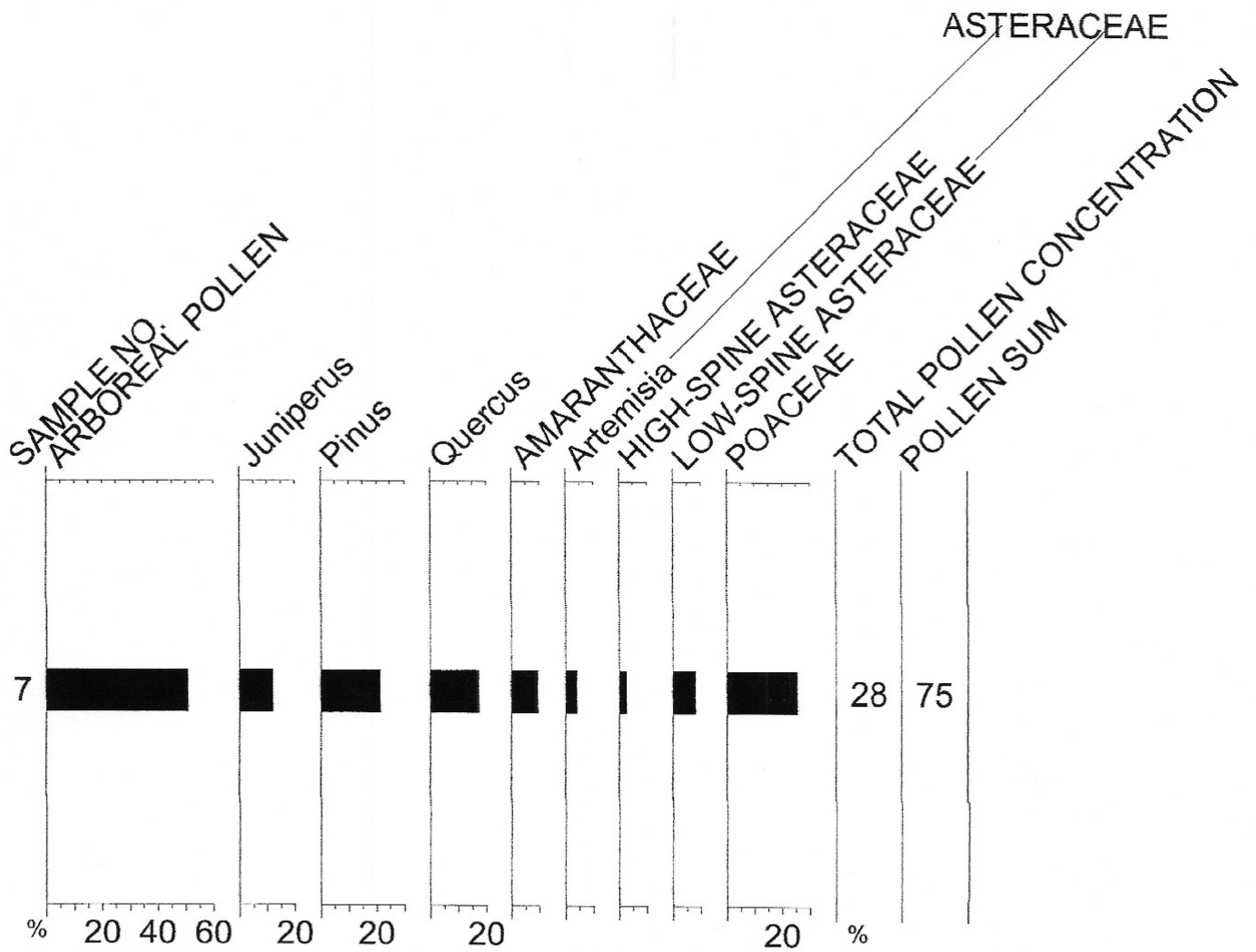


FIGURE 1. POLLEN DIAGRAM FOR A MANO.

POLLEN TYPES OBSERVED IN SAMPLES FROM A ROCKSHELTER

Scientific Name	Common Name
ARBOREAL POLLEN:	
<i>Juniperus</i>	Juniper
<i>Pinus</i>	Pine
<i>Quercus</i>	Oak
NON-ARBOREAL POLLEN:	
Amaranthaceae	Amaranth family (now includes Chenopodiaceae, these two families were combined based on genetic testing and the pollen category "Cheno-ams")
Asteraceae:	Sunflower family
<i>Artemisia</i>	Sagebrush
Low-spine	Includes ragweed, cocklebur, sumpweed
High-spine	Includes aster, rabbitbrush, snakeweed, sunflower, etc.
Poaceae	Grass family
Total pollen concentration	Quantity of pollen per cubic centimeter (cc) of sediment

Appendix 5: Far Western XRF Navajo Pictograph Report

FAR WESTERN X-RAY FLUORESCENCE ANALYSIS REPORT (2025-10)

This report provides the results of X-ray fluorescence (XRF) trace-element analysis of 16 pictographs and one “mud offering” from three rockshelters in northwestern New Mexico. These include a small, unrecorded shelter on private land located northwest of the community of Navajo Dam in San Juan County (designated Navajo Dam site). Located along the northwest arm of Navajo Lake, this shelter lies at the north end of a roughly 20-x-40-mile area of rock art and pueblitas centered around the mesas between Navajo Lake, Gobornador Canyon, and Canyon Largo. Secondly, two large, well-documented shelters within site LA 109030, located on Bureau of Land Management land south of the community of Cuba. These shelters, located at the base of Canon Jarido are known as Ojo Jarido and Canyon Jarido. M. Kathleen Davis performed the analysis in the field. Results were reviewed in consultation with Dr. Daron Duke.

METHODS

Energy dispersive XRF (ED-XRF) analysis was conducted using a Bruker Tracer 5g handheld XRF analyzer (Serial Number 900G11334). The system is equipped with 50 kV, 4-watt, rhodium (Rh) X-ray tube and a 20 mm² SDD detector with a graphene window. The resolution of the detector is approximately 140 eV at 250,000 counts per second. Pigments were analyzed at 40 kV and 40 μ A for 30 live seconds while using a filter composed of 150 μ m copper, 25 μ m titanium, and 200 μ m aluminum in an air atmosphere. The X-ray beam focuses on an area approximately 8 mm in diameter. Pigment areas range from approximately one to more than 20 cm in diameter.

Analysis focused on the region of the spectrum between approximately 4.0 and 13.0 keV. Spectra were examined for the presence or absence of manganese (K-alpha peaks), iron (K-alpha peaks) and mercury (L-alpha peaks) and/or an increase in peak height relative to scans of adjacent residue-free surfaces of bedrock. For the mud offering adhering to the shelter wall, the spectrum was compared to that of mud at the shelter entrance. Spectra were analyzed in Artax software available through Bruker/Nano, and scans of pigment and adjacent bedrock were normalized to the Compton scatter peak of rhodium from the X-ray tube in an effort to account for differences in count rate. The instrument’s on-board camera was used to focus the X-ray beam on the pigment.

RESULTS

Nearly all pigments show an increase in iron over the adjacent bedrock, although the increases observed in the faint pigments at Navajo Dam are small. This suggests that the pigments are derived from either hematite (the red pigments) or magnetite (the black pigments) (Table 1, Figures 1-18). There are two exceptions: a black element at the Ojo Jarido shelter that displays an increase in manganese (Figure 9), and the black border of the large sun pictograph at Canyon Jarido. A scan of the right side of this border (Figure 13) shows large lead peaks, suggesting that the pigment was derived either from galena, or that it was added or modified in modern times with lead paint. Photos are provided in Figures 19-31.

Table 1. Elements Identified in Pigments.

Figure	PDZ files	Pictograph Number	Pigment Color	Elements Identified
1, 19	1263	Navajo Dam, Star 1	Black	Iron
2, 20	1265, 1266	Navajo Dam, Star 2	Black	Iron
3, 21	1267, 1268	Navajo Dam, Star 3	Black	Iron
4, 22	1270	Navajo Dam, Star 4	Black	Iron
5	1271	Navajo Dam, Star 5	Black	Iron
6, 23	1273	Navajo Dam, Star 6	Black	Iron
7, 24	1238, 1239	Ojo Jarido, Star 1	Red	Iron
8, 25	1240, 1241	Ojo Jarido, Star 2	Red	Iron
9, 26	1242	Ojo Jarido, amorphous	Black	Manganese
10, 27	1244	Ojo Jarido, handprint	Orange	Iron
11	1245	Ojo Jarido, mud offering	-	Trace element profile Identical to spring mud
12, 28, 29	1250	Canyon Jarido, center of sun	Red	Iron
13, 28, 29	1252	Canyon Jarido, black edge right side of large sun	Black	Lead
14, 28, 29	1253	Canyon Jarido, top sun ray	Red	Iron
15, 28, 29	1254	Canyon Jarido, black edge left side of large sun	Black	Iron
16, 28, 29	1255	Canyon Jarido, center of moon	Red	Iron
17, 30	1256	Canyon Jarido, bear	Black	No increase over bedrock
18, 31	1258	Canyon Jarido, chicken (modern)	Black	No increase over bedrock

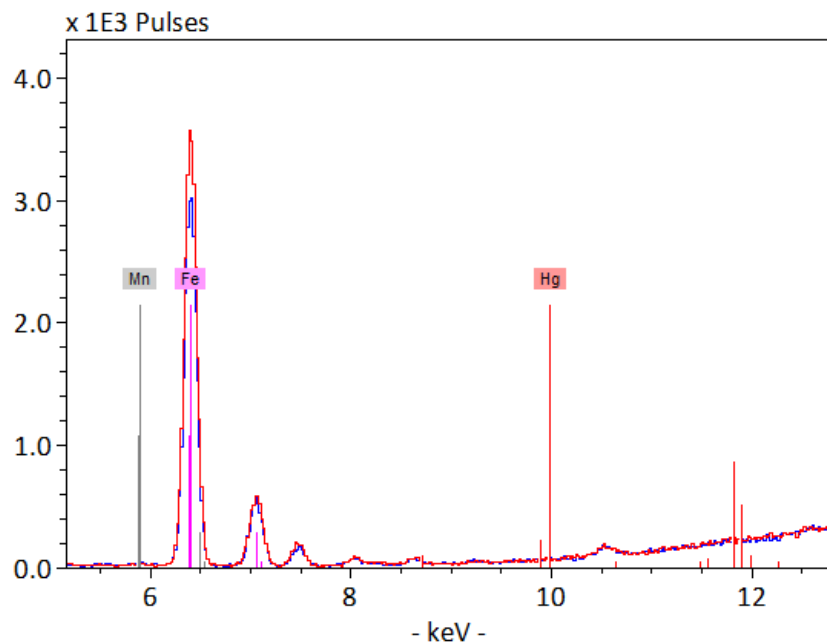


Figure 1. Navajo Dam, Star 1. Pigment in red, bedrock in blue. Note slight increase in iron (Fe) in the pigment and absence of manganese (Mn) and mercury (Hg).

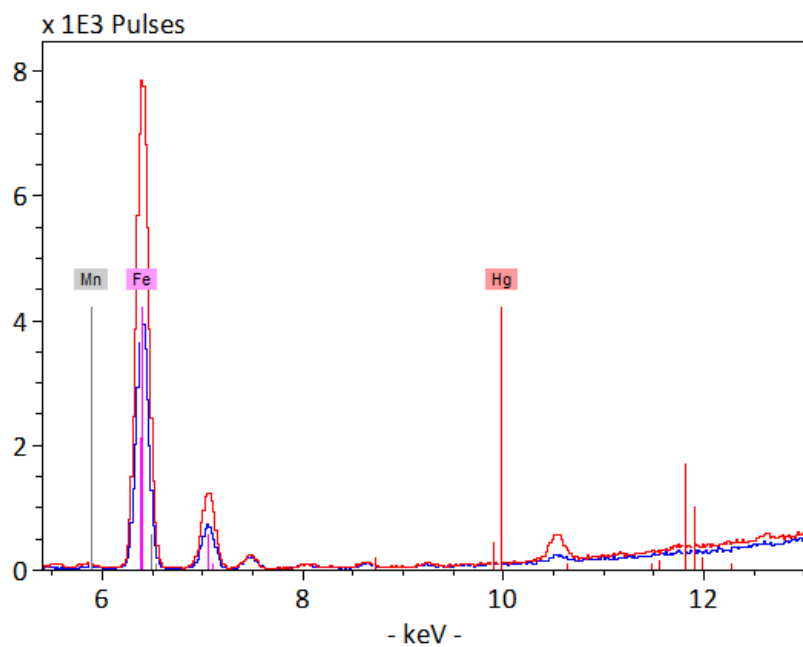


Figure 2. Navajo Dam, Star 2. Pigment in red, bedrock in blue. Note increase in iron (Fe) and absence of manganese (Mn) and mercury (Hg).

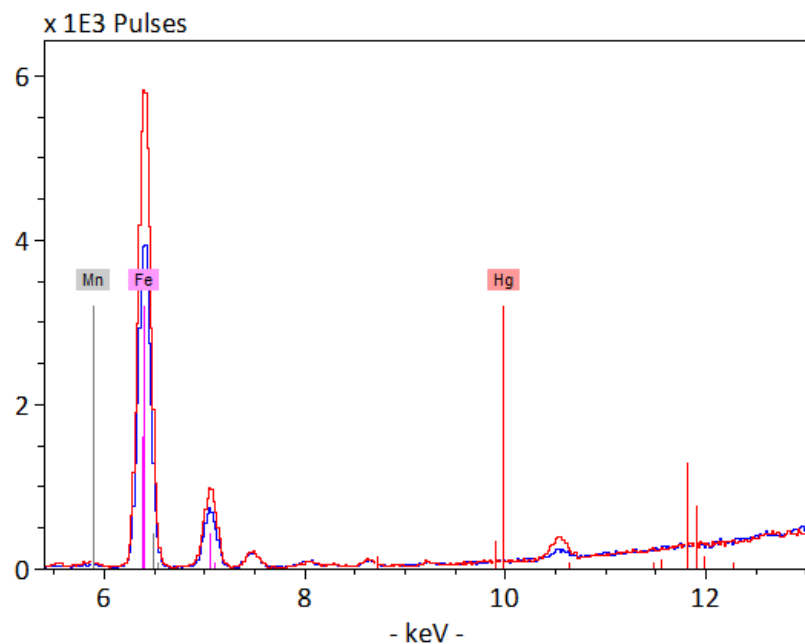


Figure 3. Navajo Dam, Star 3. Pigment in red, bedrock in blue. Note increase in iron (Fe) and absence of manganese (Mn) and mercury (Hg).

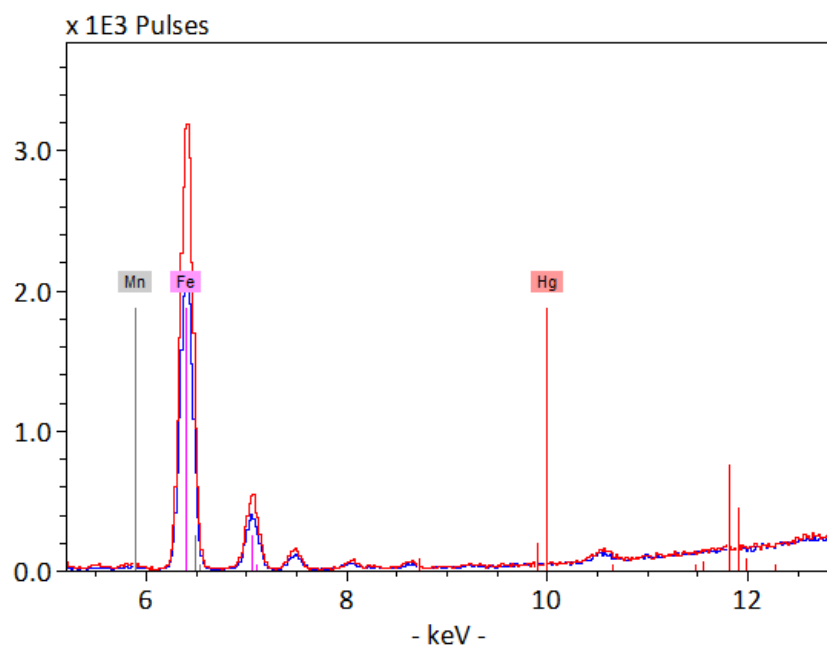


Figure 4. Navajo Dam, Star 4. Pigment in red, bedrock in blue. Note small increase in iron (Fe) and absence of manganese (Mn) and mercury (Hg).

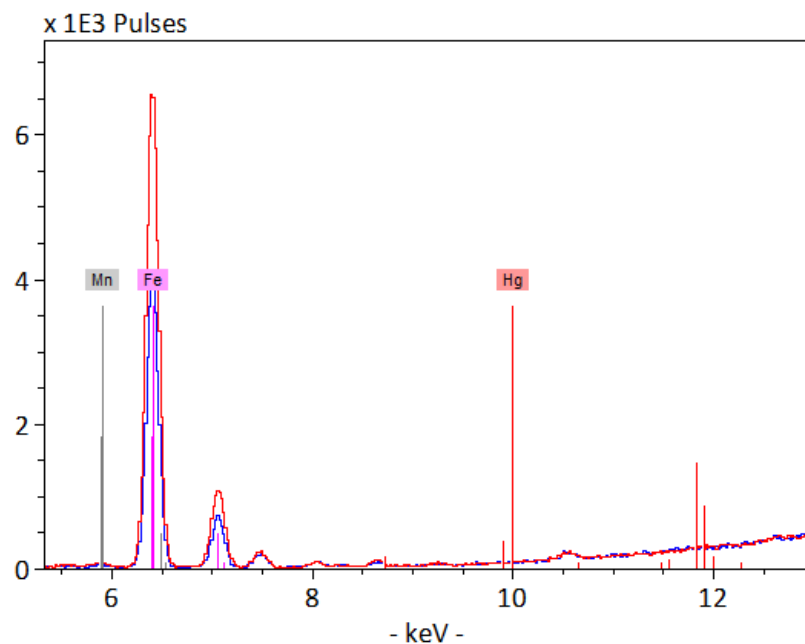


Figure 5. Navajo Dam, Star 5. Pigment in red, bedrock in blue. Note small increase in iron (Fe) and absence of manganese (Mn) and mercury (Hg).

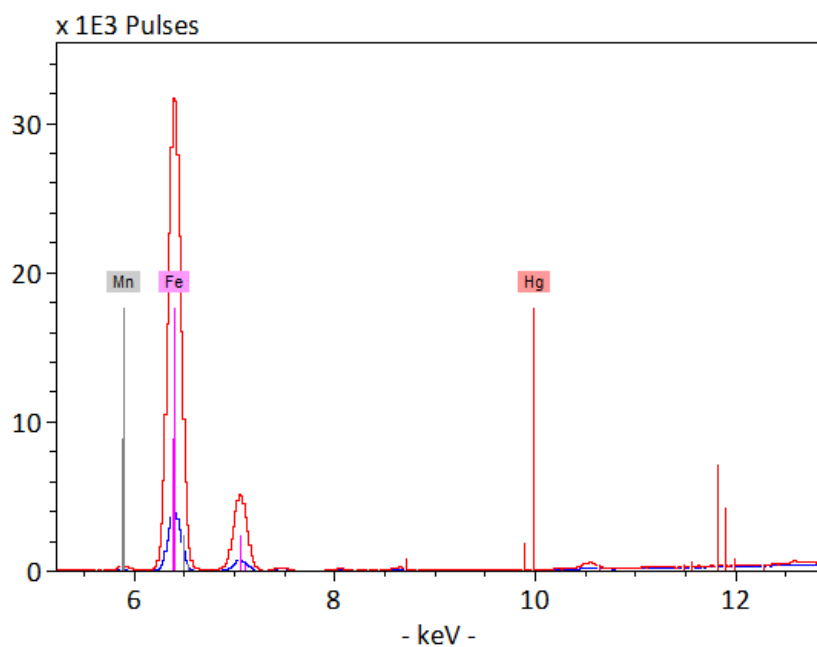


Figure 6. Navajo Dam, Star 6. Pigment in red, bedrock in blue. Note small increase in iron (Fe) and absence of manganese (Mn) and mercury (Hg).

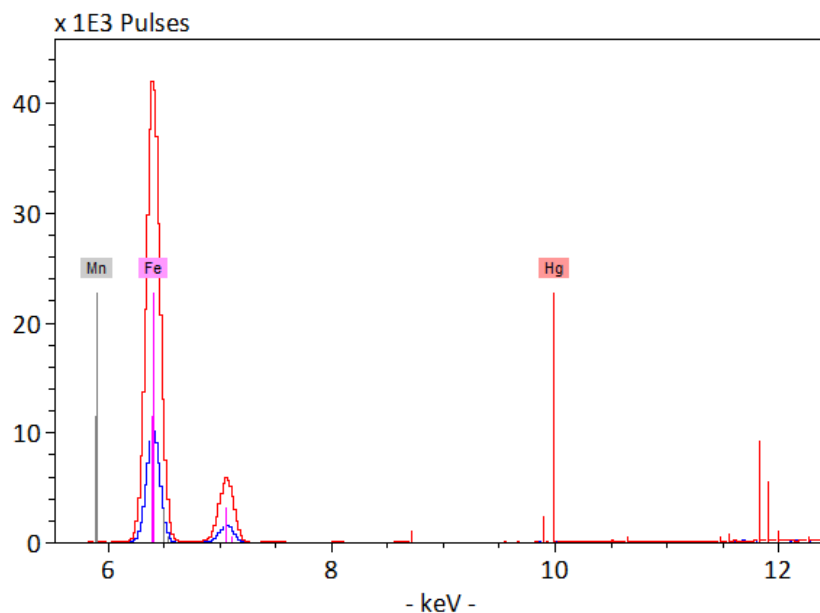


Figure 7. Ojo Jarido, Star 1. Pigment in red, bedrock in blue. Note the higher peak of iron (Fe) in the pigment and absence of manganese (Mn) and mercury (Hg).

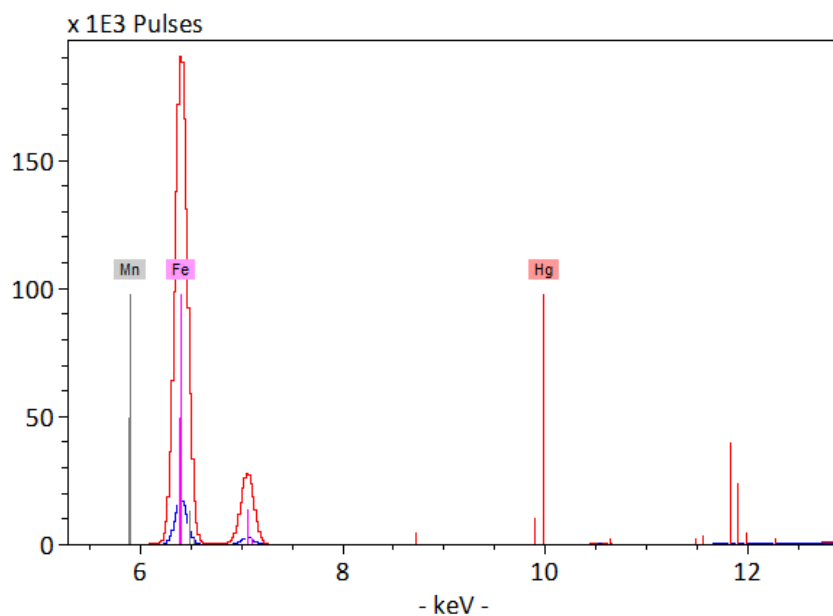


Figure 8. Ojo Jarido, Star 2. Pigment in red, bedrock in blue. Note substantially higher peak of iron (Fe) in the pigment and absence of manganese (Mn) and mercury (Hg).

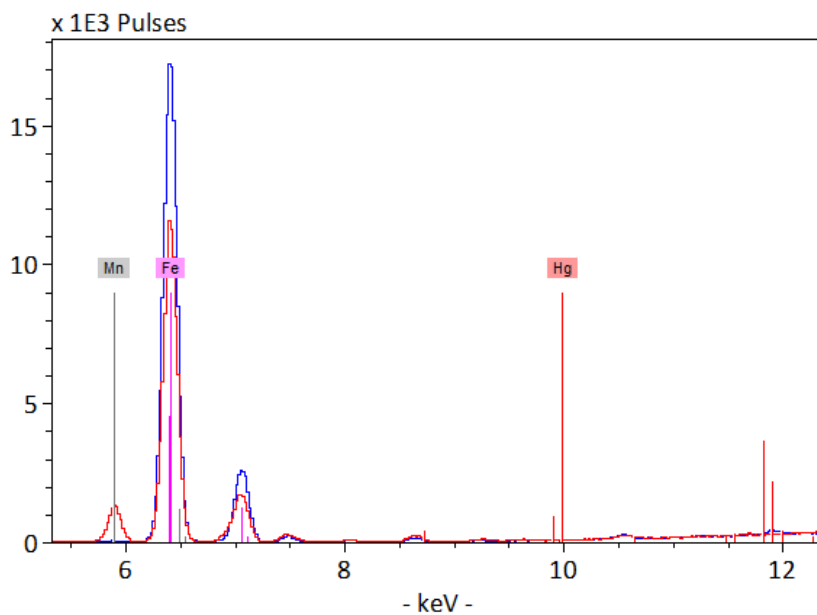


Figure 9. Ojo Jarido, amorphous black pictograph. Pigment in red, bedrock in blue. Note lower iron peak (Fe) but presence of a small manganese (Mn) peak. Mercury (Hg) is absent.

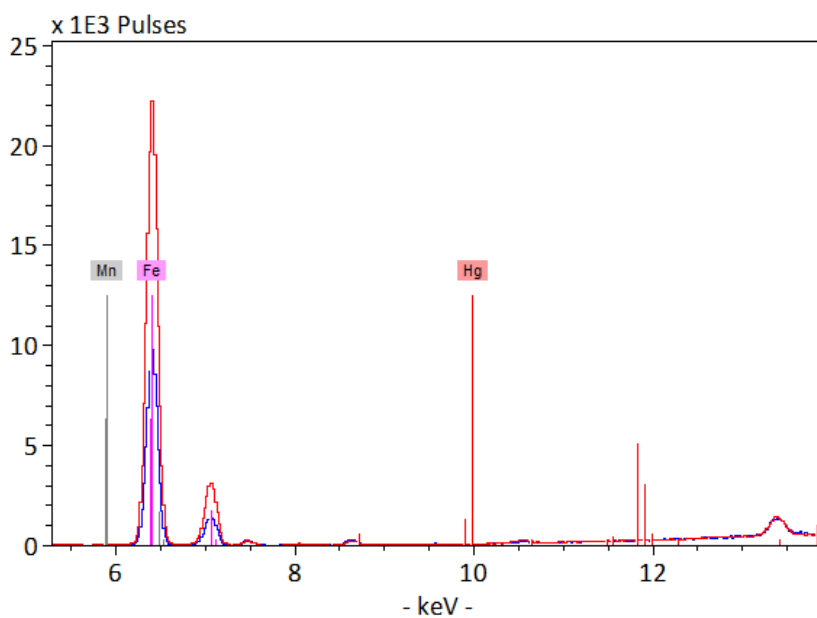


Figure 10. Ojo Jarido, handprint (small). Pigment in red, bedrock in blue. Note Increase in iron (Fe). Manganese (Mn) and mercury (Hg) are absent.

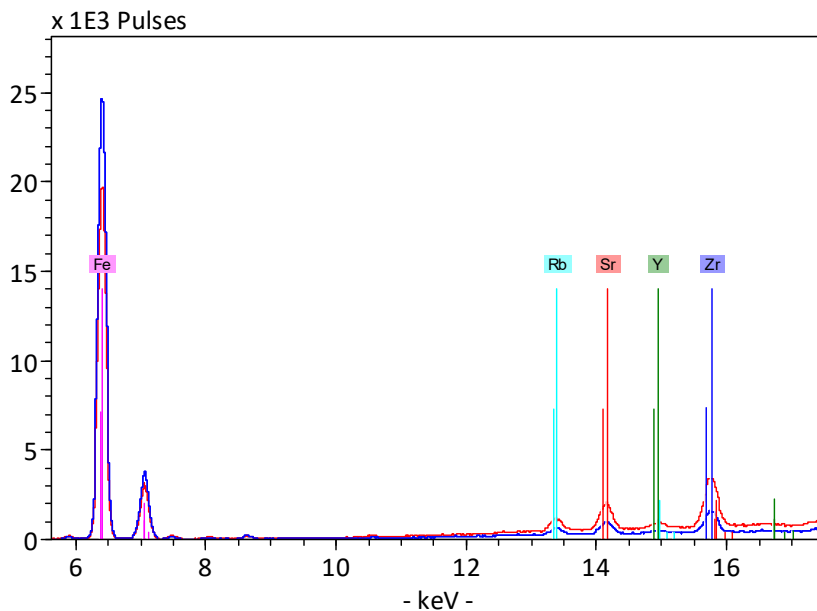


Figure 11. Ojo Jarido, mud offering on shelter wall (in red) compared to dry mud at shelter entrance (blue). Note similar profile of iron (Fe), and trace elements rubidium (Rb), strontium (Sr), Y (yttrium), and zirconium (Zr).

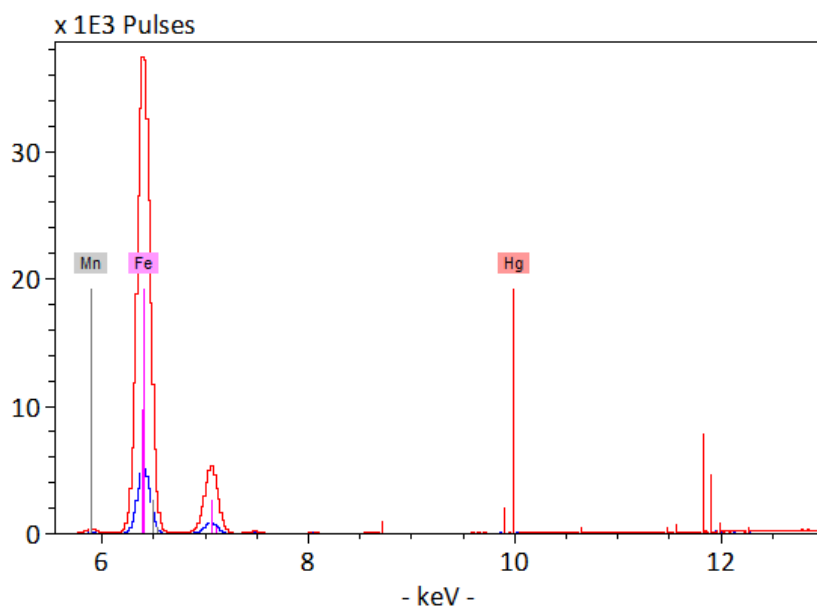


Figure 12. Canyon Jarido, center of large sun pictograph. Pigment in red, bedrock in blue. Note large increase in iron (Fe) and absence of manganese (Mn) and mercury (Hg).

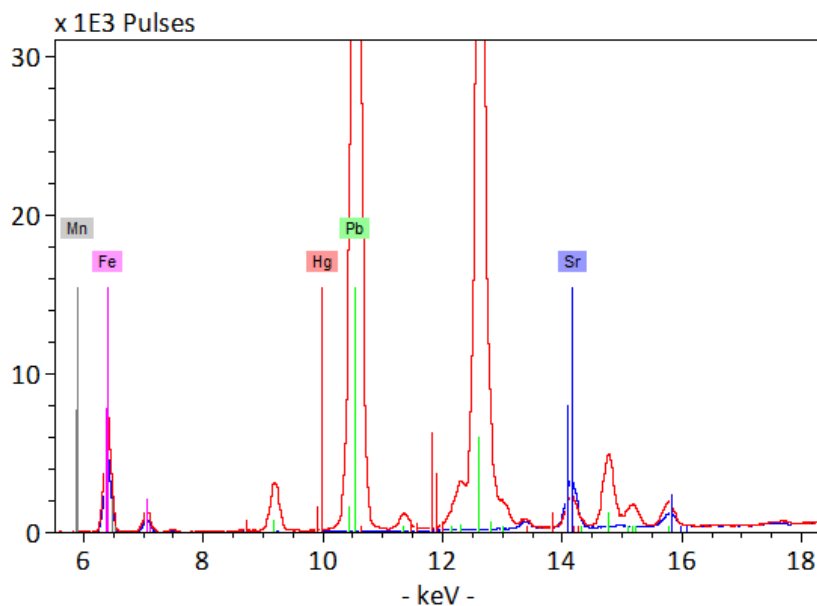


Figure 13. Canyon Jarido, black edge right side of large sun. Pigment in red, bedrock in blue. Spectrum is dominated by large lead peaks (all four peaks with vertical green lines).

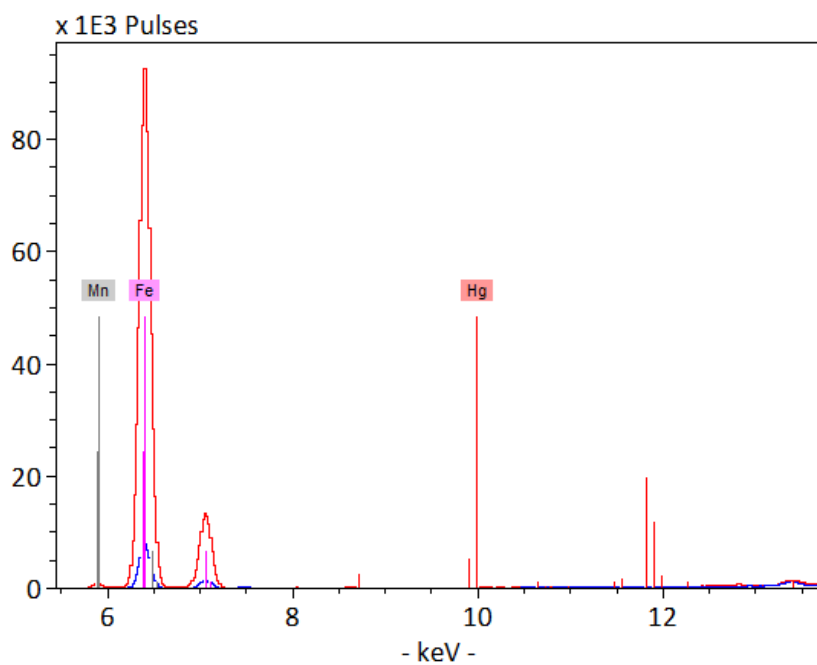


Figure 14. Canyon Jarido, top sun ray. Pigment in red, bedrock in blue. Note large iron peak and absence of manganese and lead.

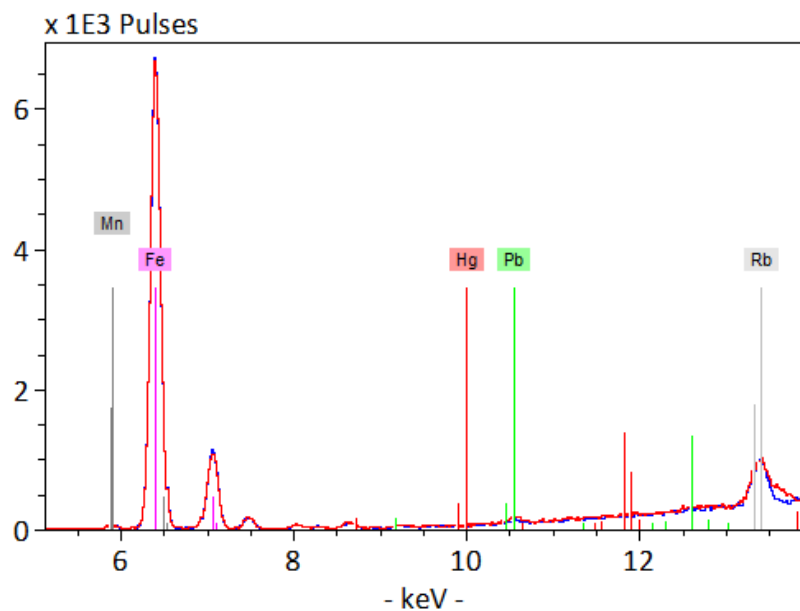


Figure 15. Canyon Jarido, black edge left side of sun. Pigment in red, bedrock in blue. Note absence of lead peaks.

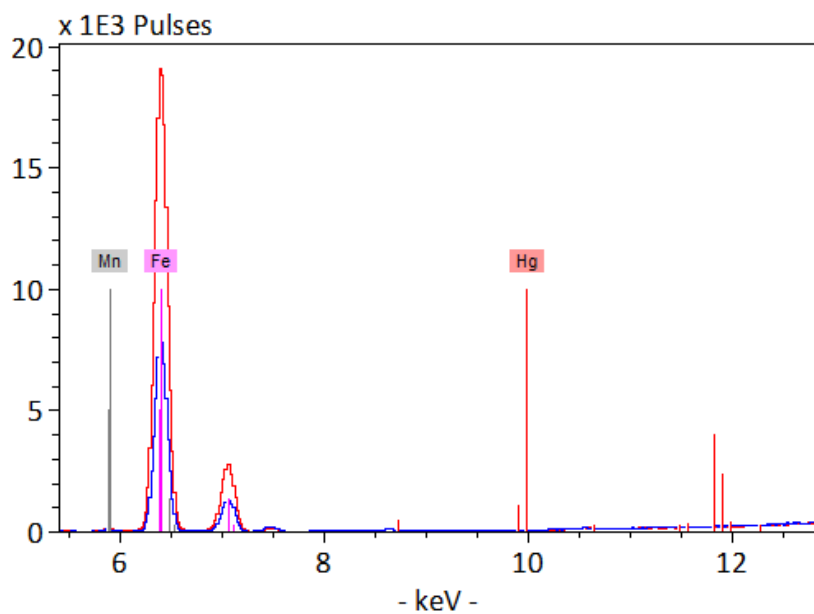


Figure 16. Canyon Jarido, center of moon. Pigment in red, bedrock in blue. Note increase in iron (Fe), absence of manganese (Mn) and mercury (Hg).

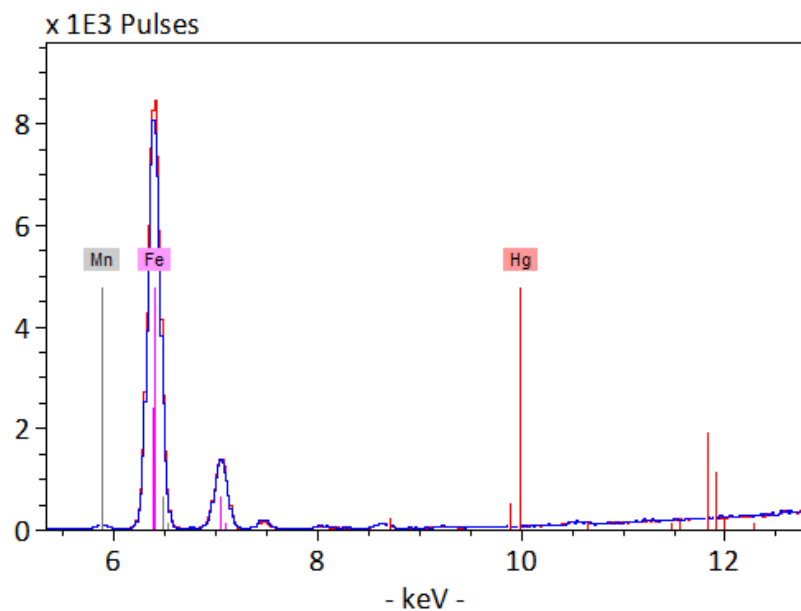


Figure 17. Canyon Jarido, bear. Pigment in red, bedrock in blue. No increase over bedrock.

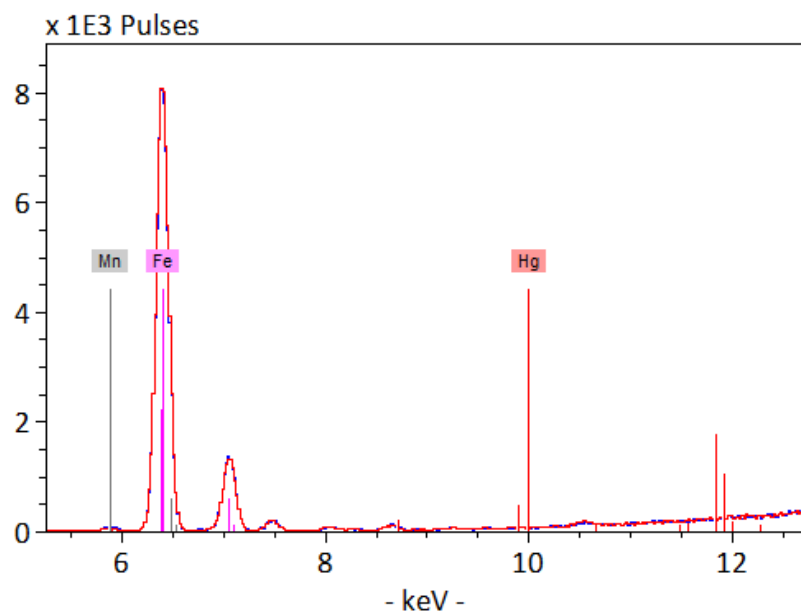


Figure 18. Canyon Jarido, chicken. Pigment in red, bedrock in blue. Presumed modern. No increase over bedrock.

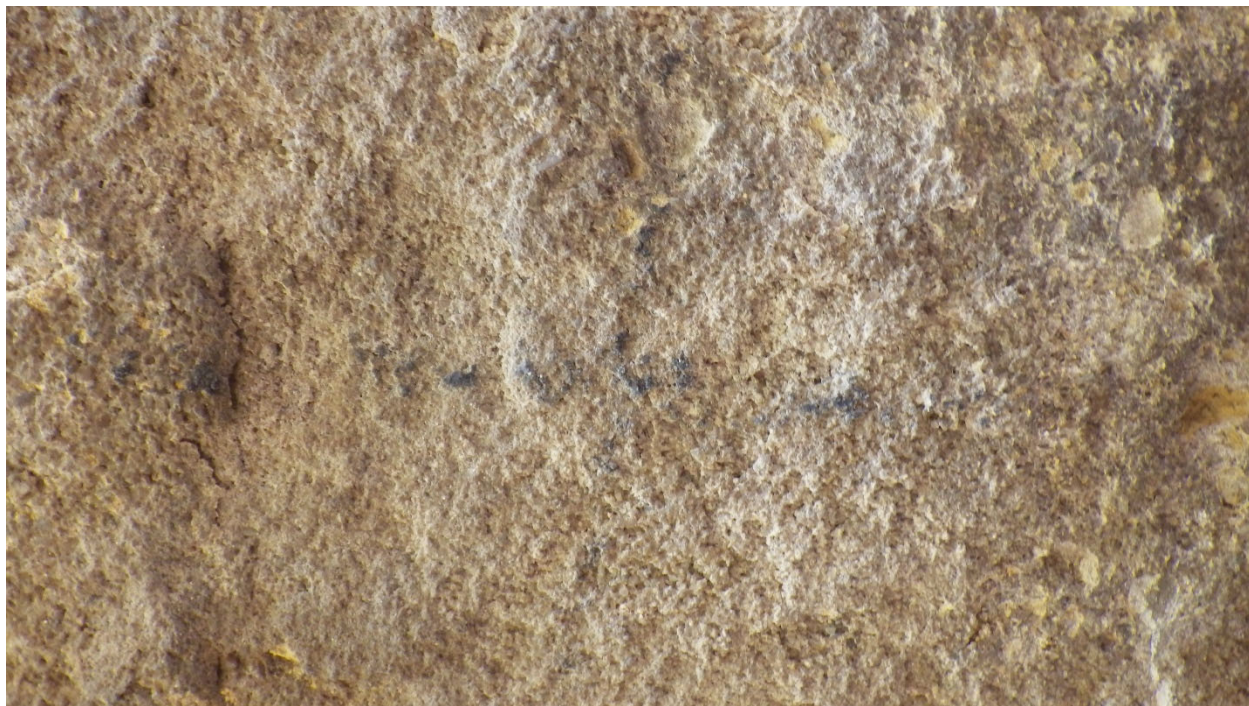


Figure 19. Navajo Dam. Alcove 2, Star 1.



Figure 20. Navajo Dam. Alcove 2, Star 2.

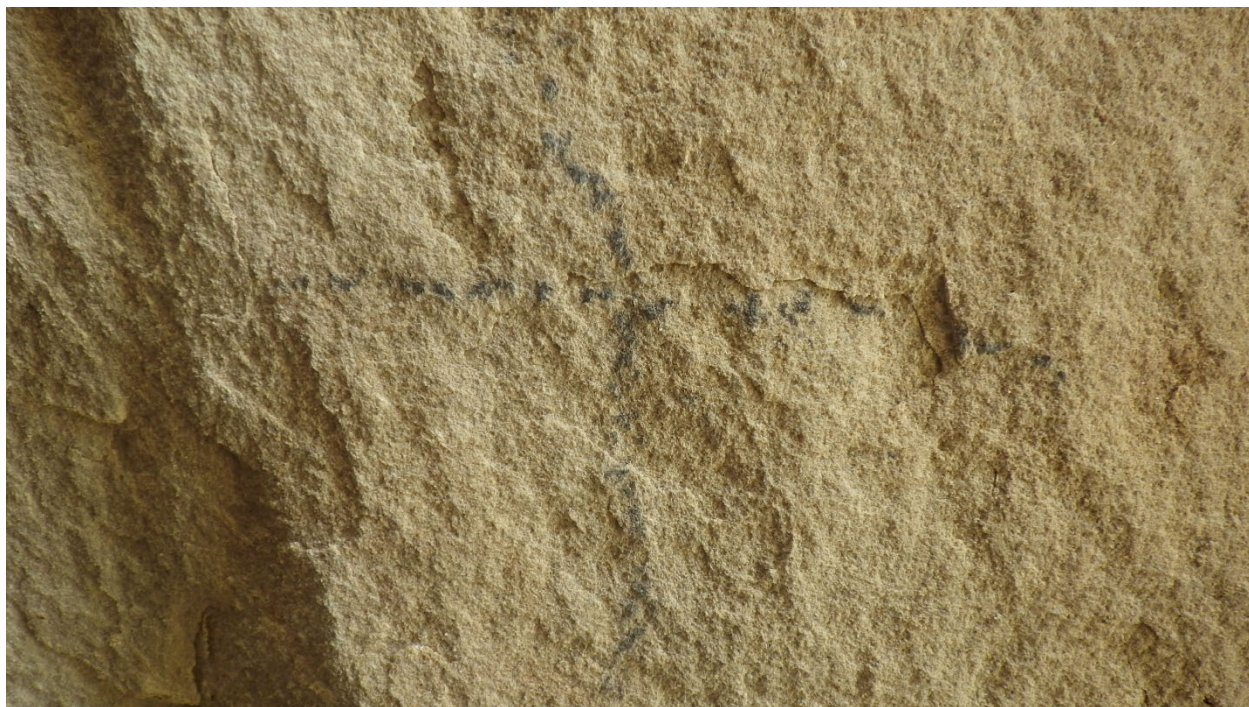


Figure 21. Navajo Dam. Alcove 2, Star 3.



Figure 22. Navajo Dam. Alcove 2, Star 4.



Figure 23. Navajo Dam. Alcove 1, Star 6.



Figure 24. Ojo Jarido, Star 1.



Figure 25. Ojo Jarido, Star 2.



Figure 26. Ojo Jarido, Amorphous Black.



Figure 27. Ojo Jarido. handprints. Large handprint left, small handprint right.



Figure 28. Canyon Jarido. Sun to left, moon to right.



Figure 29. Canyon Jarido. Sun with scale at 4 ft. Note black pigment around red center.



Figure 2. Canyon Jarido. Bear, scale at 2 ft.

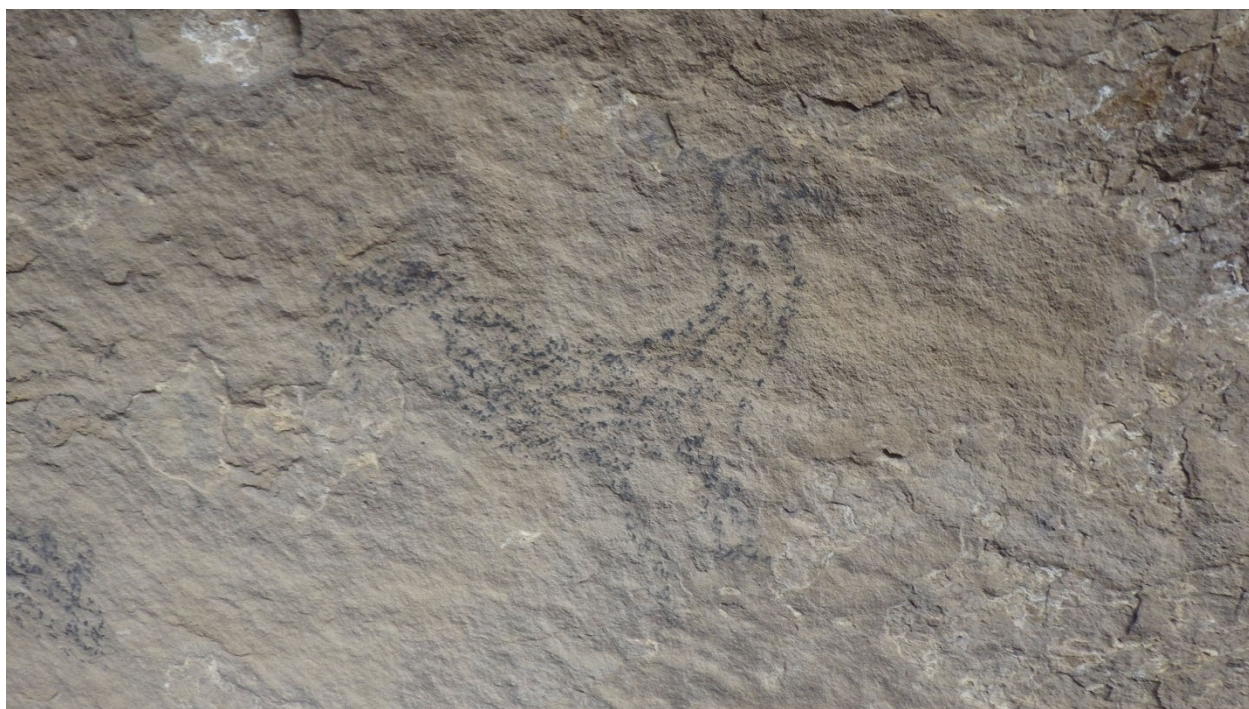


Figure 30. Canyon Jarido. Chicken (modern).

Appendix 6: INFRA-ART's Results of the XRF Analysis

Results of the XRF analysis

Sample ID	Description	XRF-Detected Elements *		
		Major	Minor	Trace
1237	Ojo Jarido bedrock	Fe	Ca, Sr, Rb	K, Zr, Si, S, Sn, Zn, Ti, Br, Ba, As, Pb, Al
1238	Ojo Jarido Star 1	Fe	Ca, Sr, Rb	Zr, K, Mo, Sn, S, Si, Ti, Zn, Cu, Pb, Mn, As, Al
1239	Ojo Jarido Star 1	Fe	Ca, Sr	Rb, Zr, K, Mo, S, Sn, Si, Ti, Zn, As, Pb, Nb, Cu, Br, Ba, Al
1240	Ojo Jarido Star 2	Fe	Sr, Rb, Ca	Zr, K, Pb, Ti, Mo, Zn, Sn, S, Cu, Nb, Si, Cl, Ba, Al, As
1241	Ojo Jarido Star 2	Fe	Sr, Rb, Ca	Zr, K, Pb, Mo, Ti, Nb, Sn, Zn, Si, S, Cl, Cu, Cr, Al, Ba, As
1242	Ojo Jarido amorphous black	Fe, Ca	Sr, Rb, Zr, K, Mn	Ti, S, Zn, Si, Mo, Nb, Pb, Al, As
1243	Ojo Jarido bedrock near handprints	Fe	Sr, Rb, K, Zr, Ca	Zn, Ti, Si, Sn, Mo, Cu, Ba, As, Al
1244	Ojo Jarido small handprint	Fe	Sr, Rb, Zr	K, Ti, Si, Sn, Zn, Ca, As, Pb, Cu, Mn, Al
1245	Ojo Jarido mud offering	Fe	Zr, Ca, Sr	Rb, K, Ti, Si, Mo, Sn, S, Zn, Mn, Pb, Cu, Ba, Al
1246	Ojo Jarido adjacent mud	Fe	Zr, Sr	Ti, Rb, K, Ca, Zn, Mo, Si, Sn, Mn, Nb, Pb, Cu, Al, Br, Ba
1250	Canyon Jarido Alcove 2 center of sun	Fe	Sr, Ca	Rb, Zr, K, Mn, Mo, Ti, Sn, S, Si, Nb, Cu, Ba, Al, Pb
1251	Canyon Jarido bedrock	Ca, Fe, Sr	Rb, Zr, K	S, Sn, Mo, Ti, Zn, Si, Mn, Pb, Cu, Al
1252	Canyon Jarido black around sun	Pb	Fe, Ca, Sr, S	Se, Rb, Sn, Ga, Ti, Mo, K, Zr, Si, Al, As, Mn
1253	Canyon Jarido top sun ray	Fe	Sr, Ca, Zr	Rb, Mn, S, K, Ti, Zn, Sn, Si, Mo, Cu, Pb, Al, Nb, Ba, Hg
1254	Canyon Jarido more black around sun	Fe, Ca, Sr	Rb, Zr	K, Mo, Sn, Ti, Si, S, Pb, Cu, Ba, Al
1255	Canyon Jarido moon	Fe, Ca, Sr	Rb, Zr, K	S, Ti, Sn, Mo, Si, Mn, Nb, Pb, Ba, Cu, Al
1256	Canyon Jarido bear	Ca, Fe, Sr, Zr	Rb, K	Ti, S, Mo, Sn, Zn, Si, Pb, Mn, Al
1257	Canyon Jarido bear head	Ca, Sr, Fe	Rb, Zr, K	S, Mo, Sn, Ti, Ba, Si, Zn, Cu, Al, Pb
1258	Canyon Jarido chicken head	Ca, Fe, Sr	Zr, Rb, K	S, Mo, Ti, Zn, Pb, Cu, Si, Nb, Ba, Al
1263	Navajo Dam star 1	Ca, Fe	Sr, Rb, Zr	S, Sn, Mo, K, Si, As, Cu, Ba, Zn, Nb, Al
1264	Navajo Dam Alcove 2 bedrock	Zr, Ca, Fe, Sr	S, Rb, Mo	S, Rb, Ti, Si, Nb, K, Ba, Cu, Pb, Zn, Al
1265	Navajo Dam Star 2	Sr, Ca, Fe	Zr, Rb, K, As, S	Mo, Sn, Si, Pb, Ba, Zn, Cu, Ti, Mn, Ga, Al
1266	Navajo Dam Star 2	Sr, Ca, Fe	Zr, Rb, K	As, S, Mo, Sn, Si, Ti, Ba, Pb, Zn, Cu, Mn, Ga, Al
1267	Navajo Dam Star 3	Sr, Fe, Ca	Zr, Rb, K, As	S, Mo, Sn, Si, Zn, Ti, Nb, Cu, Pb, Mn, Ga
1268	Navajo Dam Star 3	Sr, Fe, Ca	Zr, Rb, K	As, S, Mo, Sn, Si, Ti, Ba, Pb, Cu, Zn, Al, Mn, Nb
1270	Navajo Dam Star 4	Fe, Sr, Ca	Zr, Rb, K, Mo, Sn	S, Si, Ba, Pb, Cu, Zn, As, Nb, Mn, Al, Ga
1271	Navajo Dam Star 5	Fe, Ca, Sr	Zr, Rb, S, Mo	K, Sn, Si, Ti, Pb, Ba, Zn, Nb, Cu, Mn, Al, Ga
1272	Navajo Dam bedrock near Star 4	Fe, Sr, Ca	Zr, Rb, Mo, K, S	Sn, Si, As, Ba, Nb, Cu, Pb, Zn, Ti, Mn, Al, Ga
1273	Navajo Dam Star 6	Fe, Ca	Sr, Zr, Rb, K, Ti, S	Mo, Mn, Pb, Sn, Si, Zn, Nb, As, Cu, Al, Ba, Ga
1274	Navajo Dam bedrock next to Star 6	Fe, Ca	Sr, Zr, Rb, K, Ti, S, Sn, Mo	Mn, Si, Pb, Nb, Zn, Cu, Ga, Al

* identified elements are shown in order of decreasing abundance

Notes & Observations

Bedrock interferences

The bedrock is calcium-rich, and part of the Ca detected in the pigmented areas likely derives from the substrate. However, several samples show calcium levels significantly higher than those of the average bedrock, indicating an additional Ca source within the pigments themselves.

Strontium (Sr) is typically associated with calcium minerals, where it occurs as an impurity. The strong correlation between Ca and Sr across the dataset supports this interpretation. Similar to Ca, some pigmented areas (particularly several of the black-pigmented zones) display elevated Sr concentrations that may reflect contributions from specific pigments in addition to the Sr originating from the bedrock.

Other elements such as Mo, Cu, K, Ba, Rb, and Zr are clearly linked to the chemical signature of the bedrock and can therefore be excluded as representative chemical markers of pigment composition in this context.

The bedrock also exhibits elevated iron levels, though these are much lower than those measured in the red/orange pigmented areas. In the black-pigmented areas, the iron content is generally consistent with the bedrock average (except point 1273) suggesting that the detected Fe largely originates from the substrate rather than from the pigment itself.

Red pigments

For areas 1240–1241, we observe the highest iron (Fe) concentrations, clearly linked to the presence of red iron oxides (hematite). Several factors may account for the elevated Fe levels in these areas compared to others: experimental conditions (such as better contact between the XRF analyzer and the rock surface), greater pigment coverage with the analyzer window (producing therefore a stronger Fe signal), and/or state of preservation (better-preserved pictographs). The same red areas (1240–1241) also show the highest concentrations of chlorine (Cl), chromium (Cr), and niobium (Nb). These elements may serve as potential provenance trace markers. Aluminum (Al) is likewise highest in these areas, most likely reflecting the presence of aluminosilicates (such as kaolinite). The relatively low Al values are due to XRF limitations, as the technique is less sensitive to light elements (see similar low values for Mg and Si, although we would expect higher, especially in red ochres). Rubidium (Rb) is detected in the bedrock, but the red-pigmented areas 1240–1241 display a marked maximum exceeding the background levels, again suggesting pigment-related enrichment.

Mercury (Hg) is present in trace amounts throughout the bedrock—likely as impurities or inclusions—resulting in a generally uniform signal across the dataset. However, the highest Hg value occurs at point 1253, which may also serve as a useful trace marker. Bromine (Br) can also be used as a fingerprint to help determine the geological origin or source of the pigment, with highest values registered for areas 1238 and 1239.

The other red areas (1238–1239, 1250, and 1253) show comparable Fe levels among themselves but significantly higher calcium concentrations than areas 1240–1241. This elevated Ca content may reflect the presence of carbonate minerals such as calcite or calcium sulfate. Given the relatively low intensity

of the sulfur (S) lines, calcite is the most likely accessory mineral in these red ochres (all these accessory mineral could be easily confirmed via FTIR analysis).

The red–orange ochre (point 1244) exhibits a lower Fe concentration compared to the other red pigmented areas, but it shows the highest As, Si and Ti levels (within the red pigment group), suggesting that this red-orange pigment has a different source.

Black pigments

For the black-pigmented areas, several different black pigments were used:

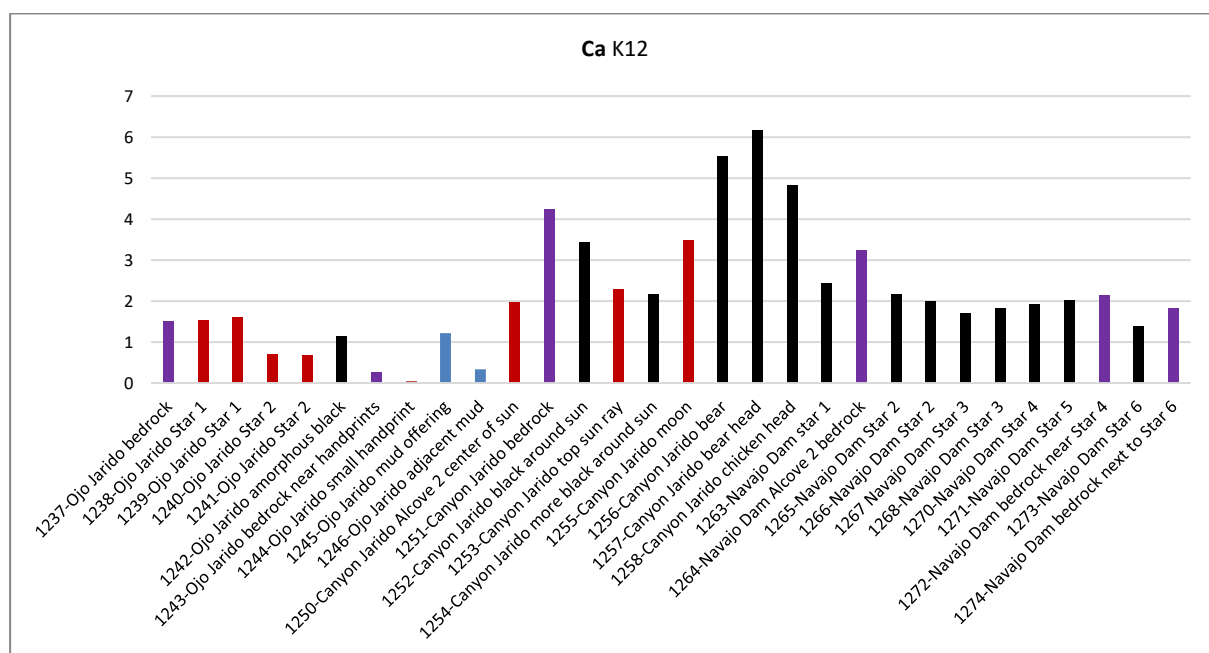
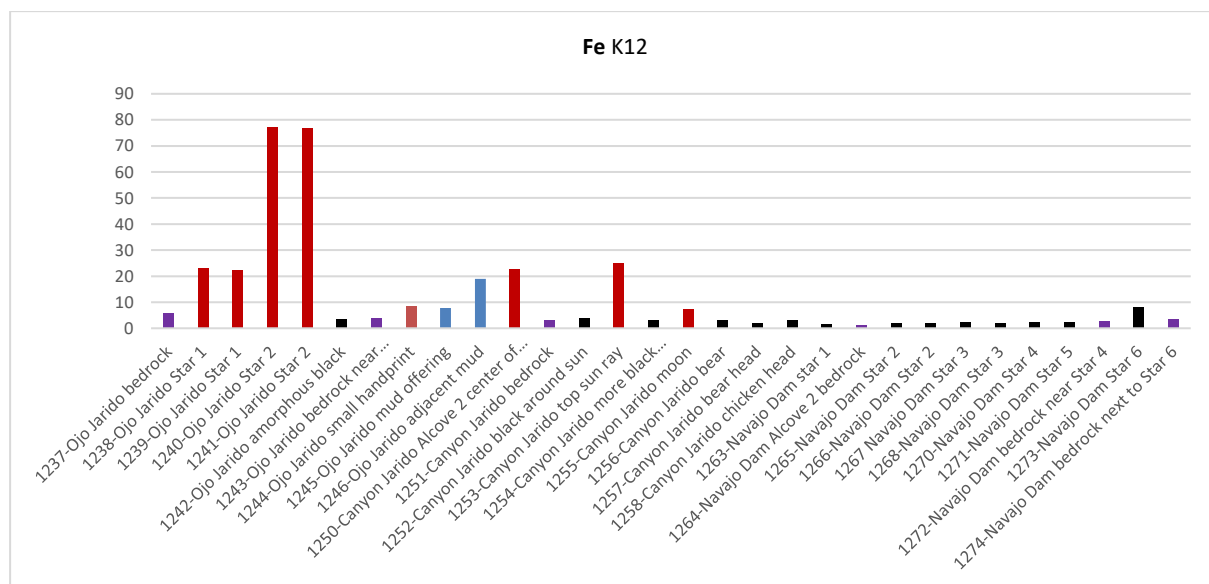
- a manganese-rich black earth (sample point 1242); the employed pigment falls within the wads category with the main coloring components based on iron oxides and manganese oxides;
- galena (sample point 1252), containing selenium impurities and gallium as a trace element. The identification is supported by the high Pb content (major element) and the corresponding S levels (minor component). The presence of selenium—a distinctive trace element in this area—indicates a selenium-bearing galena, as Se can substitute for S within the crystal lattice. In this area, Ga and S exhibit the highest peak values relative to the rest of the dataset, while Se is uniquely distinctive, being detected only here.
- bone black (one or more varieties, indicated by the high calcium content. Sample areas 1256 to 1258 display the highest peak values of calcium (relative to the full dataset), the content being most probably associated with the presence of calcium phosphate and calcium carbonate. Sample point 1257 shows the highest Sr level; in this case, the elevated Sr is linked to its incorporation into the bone mineral hydroxyapatite due to its chemical similarity to calcium. The black areas 1265–1268 exhibit the highest arsenic peak values. In bone black pigments, this trace element is typically associated with the dietary intake of the animals, as As can accumulate in bone tissue over time.

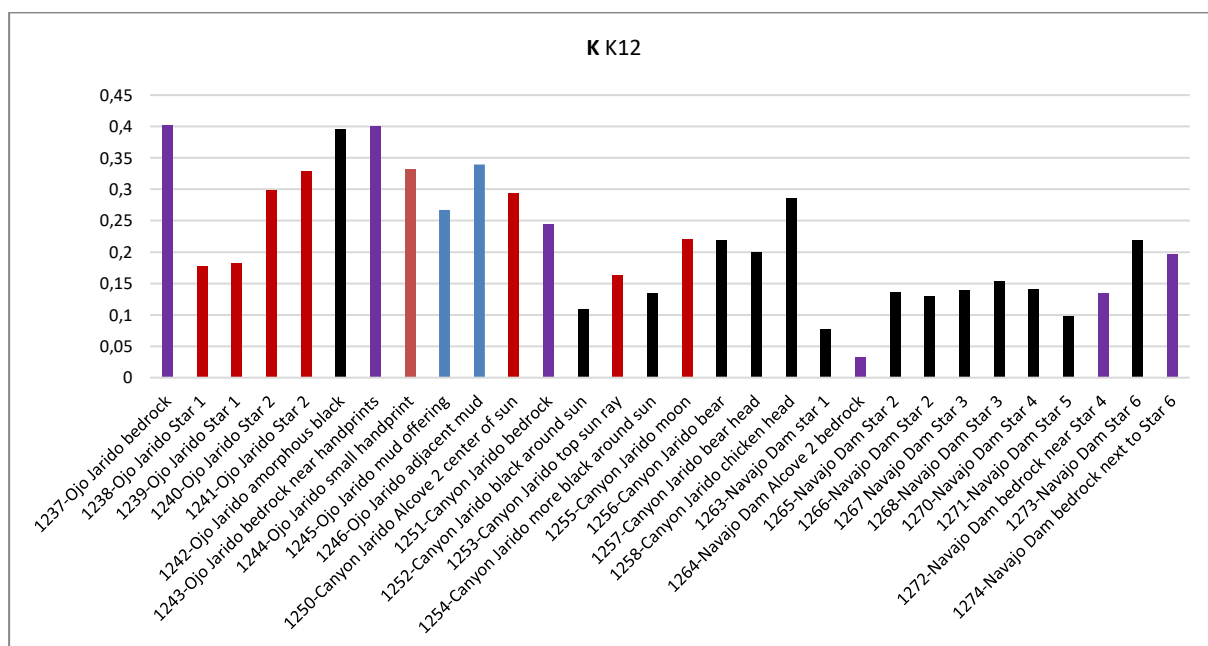
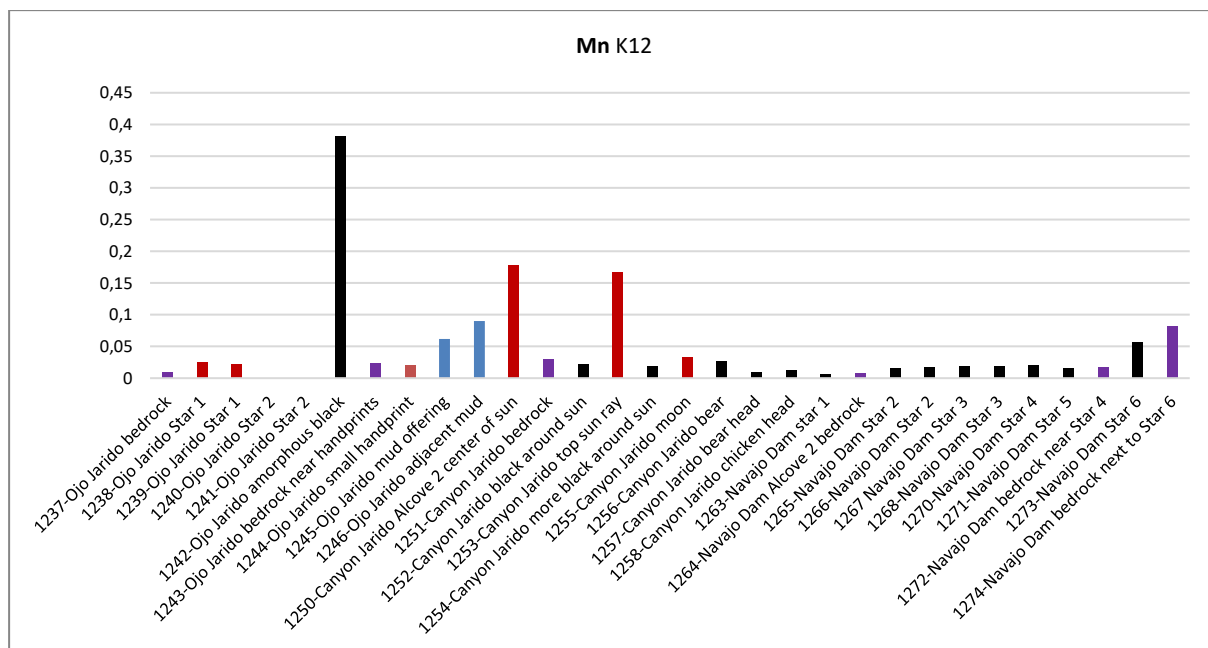
Point sample 1273 – (star 6, the possible repainting) shows the highest Fe, Cr, and Ti concentrations among the black-pigmented areas examined, and it has the second-highest Mn content—surpassed only by sample area 1242, which is the manganese-rich pigment. It also shows the highest Cl content among the black pigmented areas. The overall chemical fingerprint, when compared with the other black-pigmented areas, suggests the use of a different black earth possible applied over an original degraded bone black pigment.

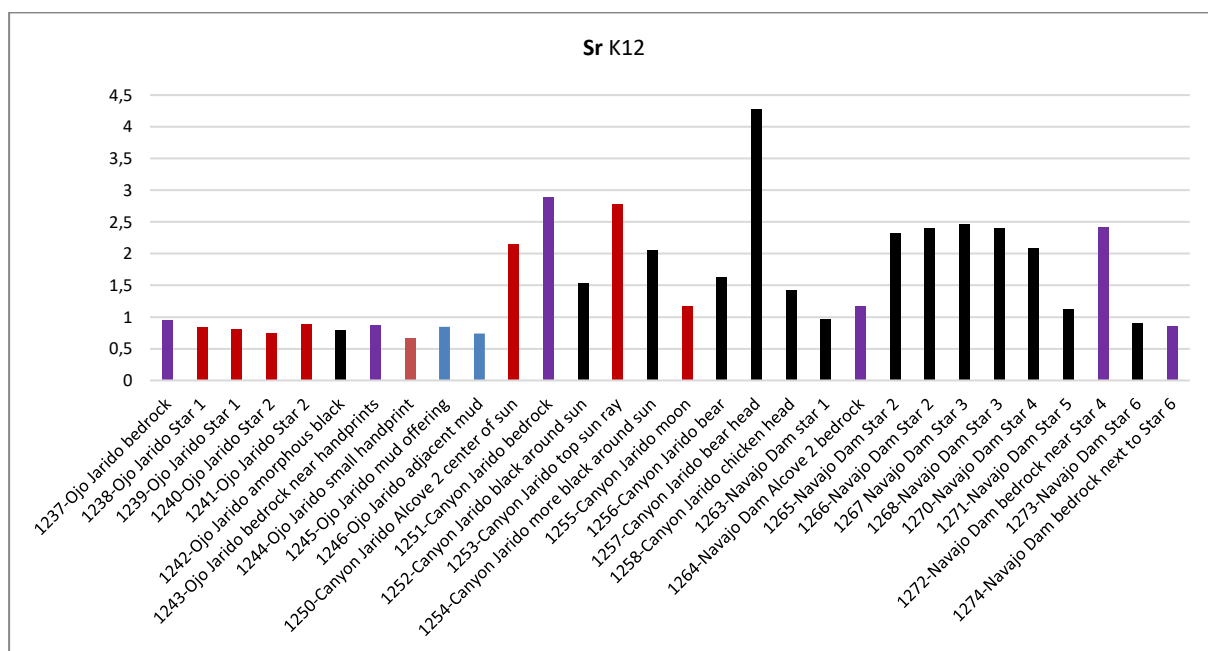
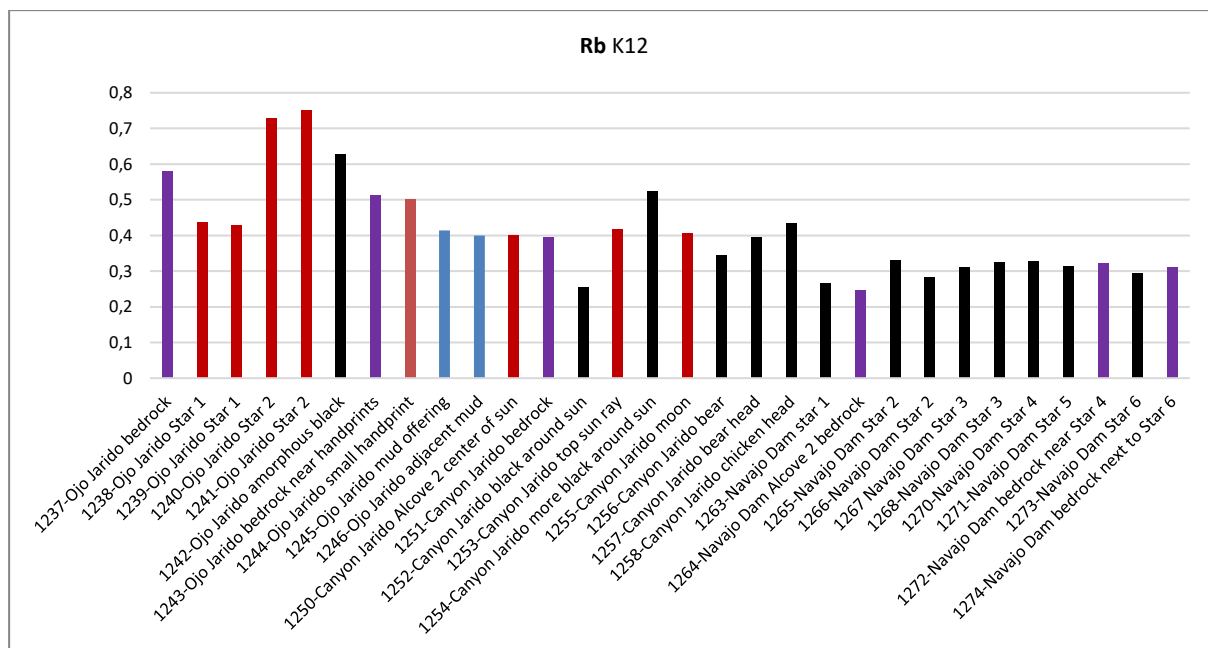
Elemental distribution across all analyzed areas

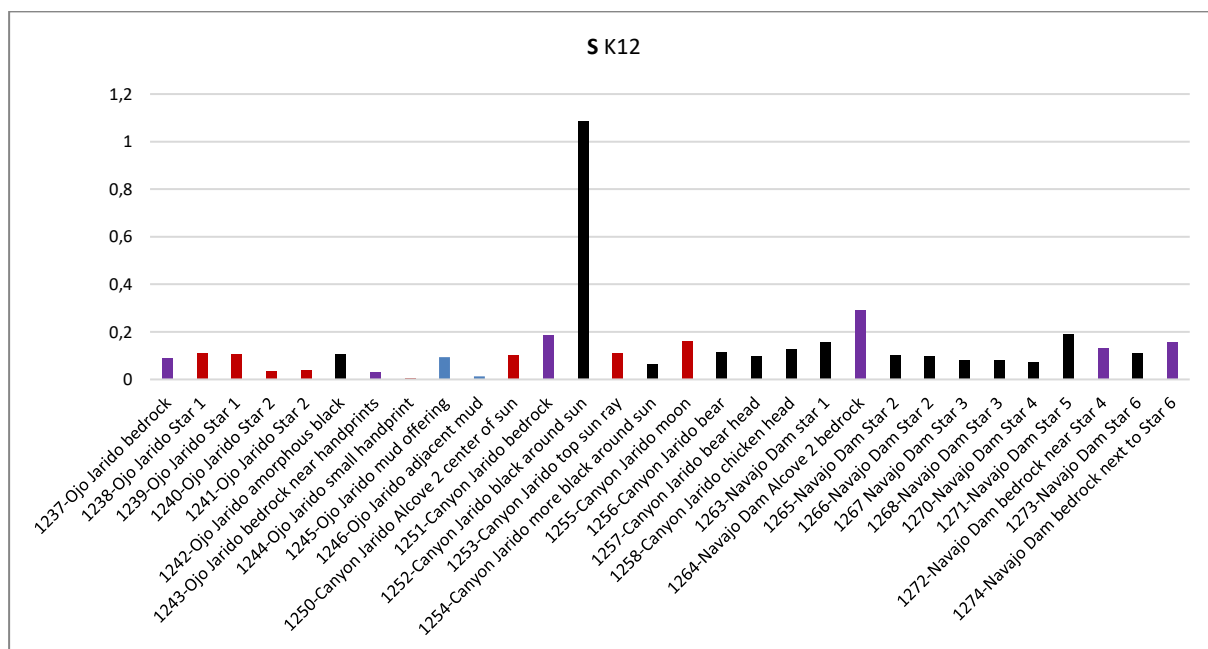
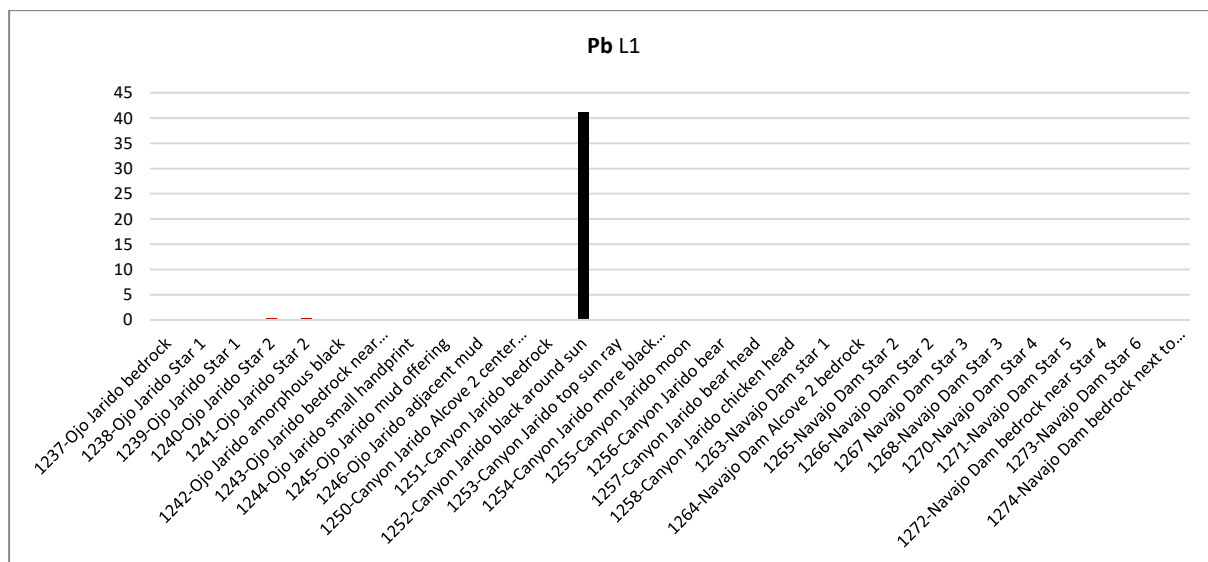
Legend

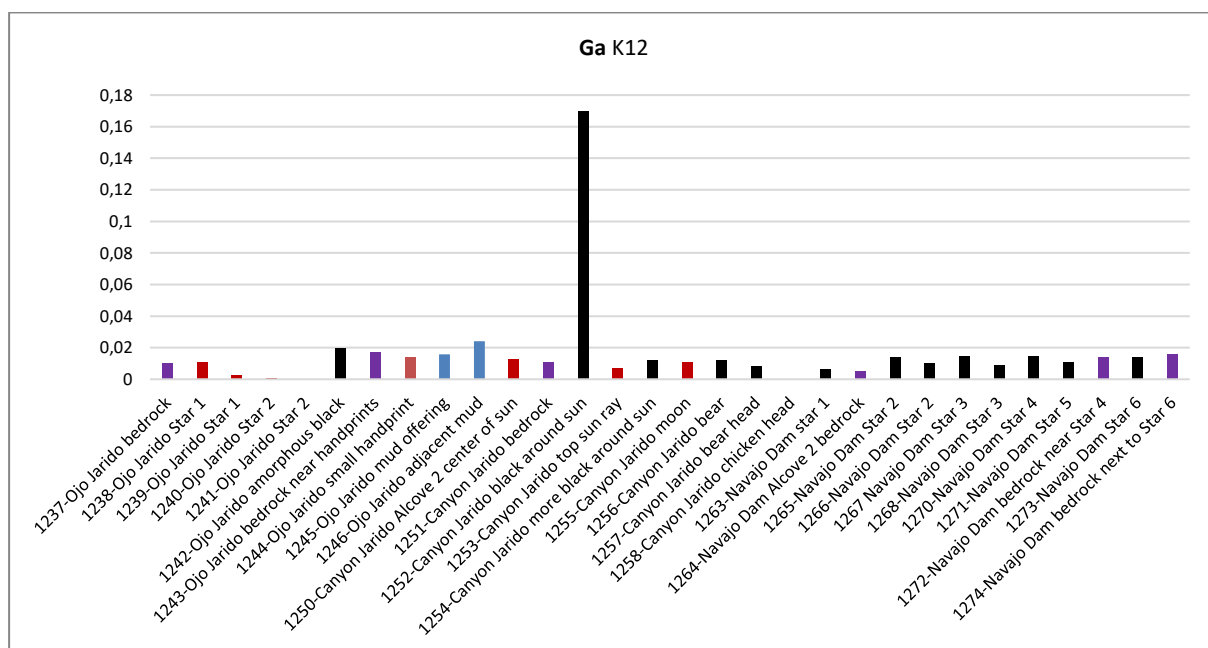
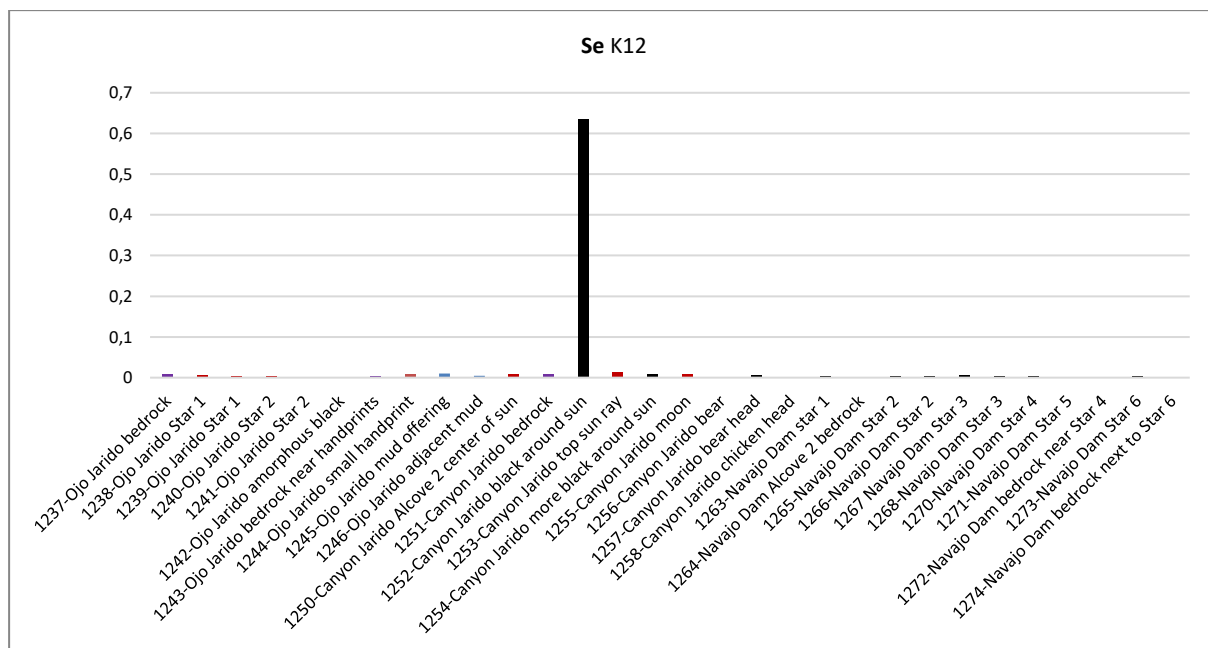
- Red pigmented areas
- Black pigmented areas
- Mud offering
- Bedrock

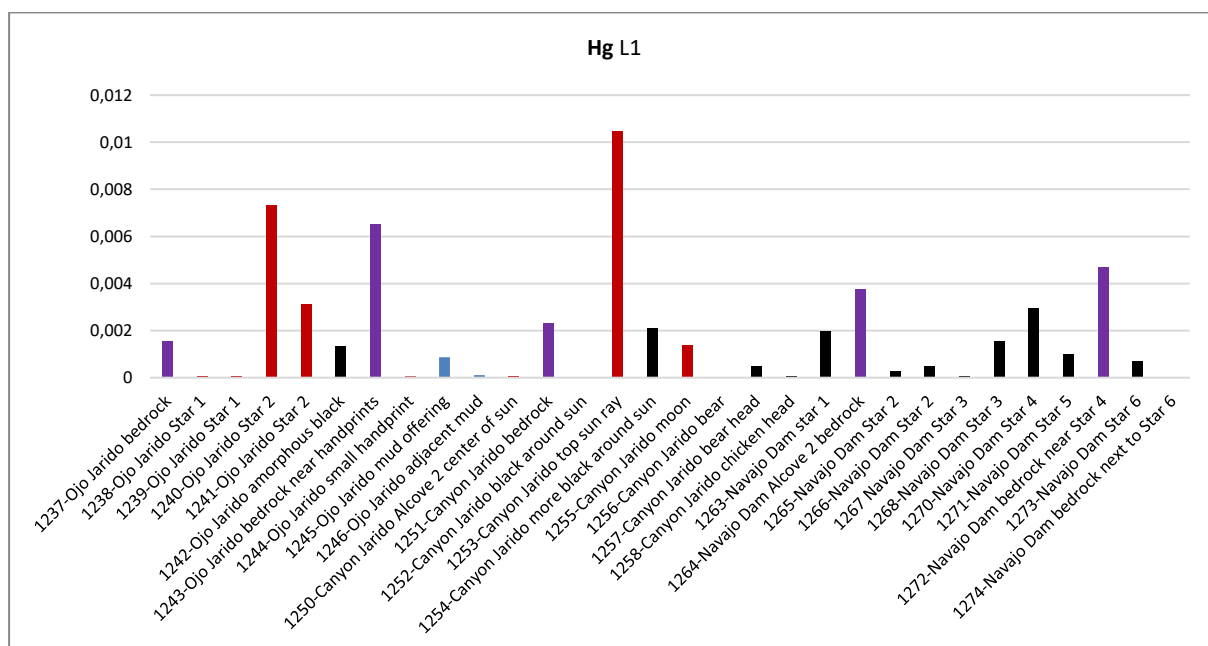
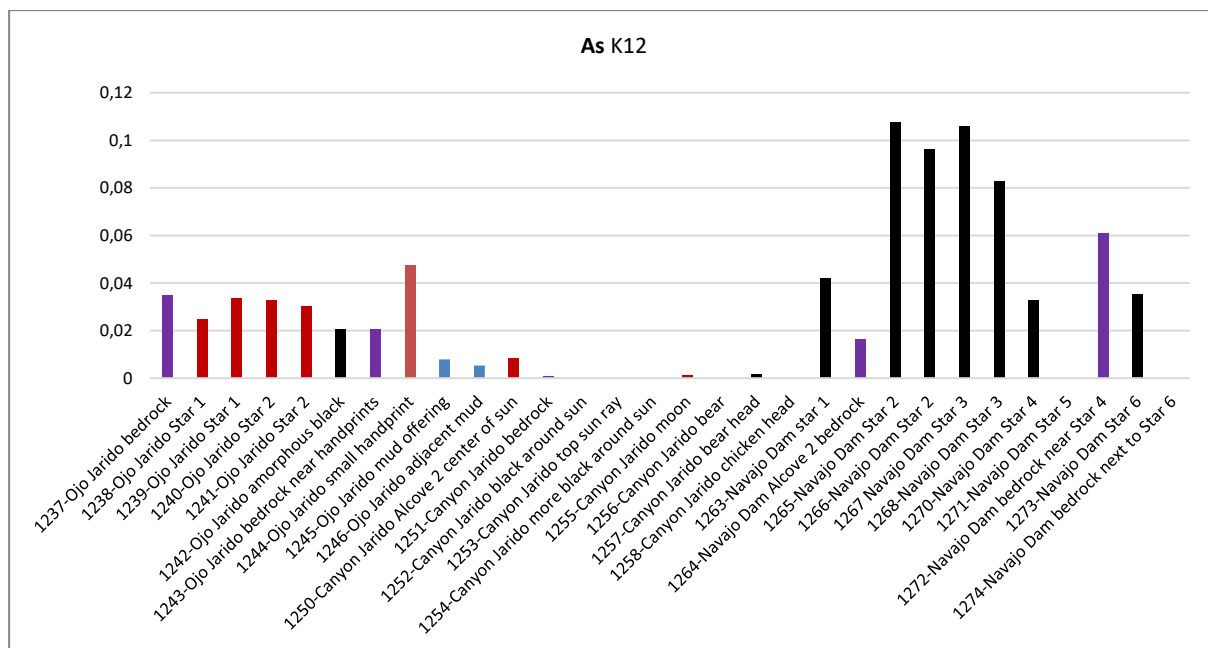


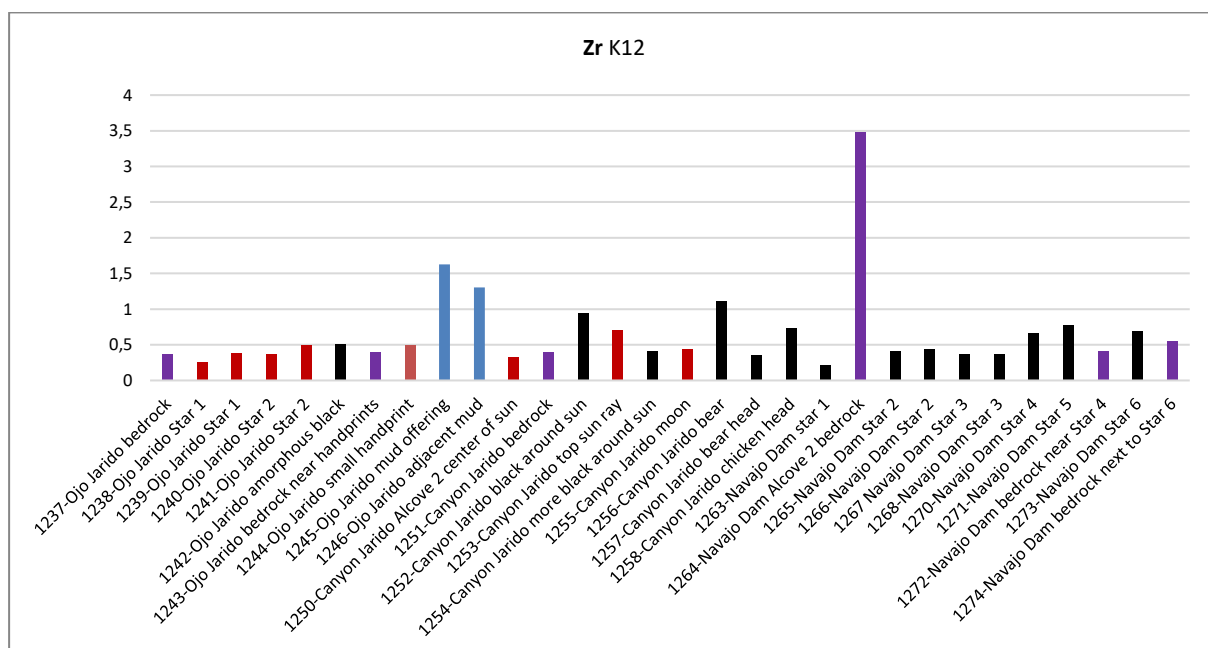
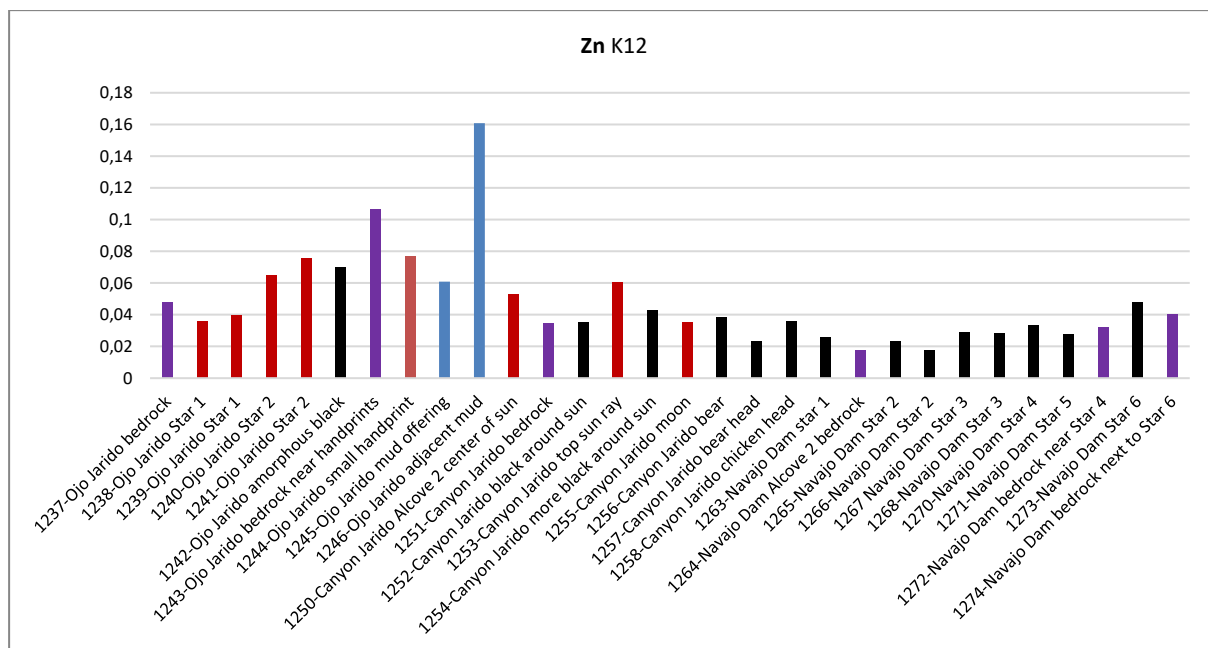


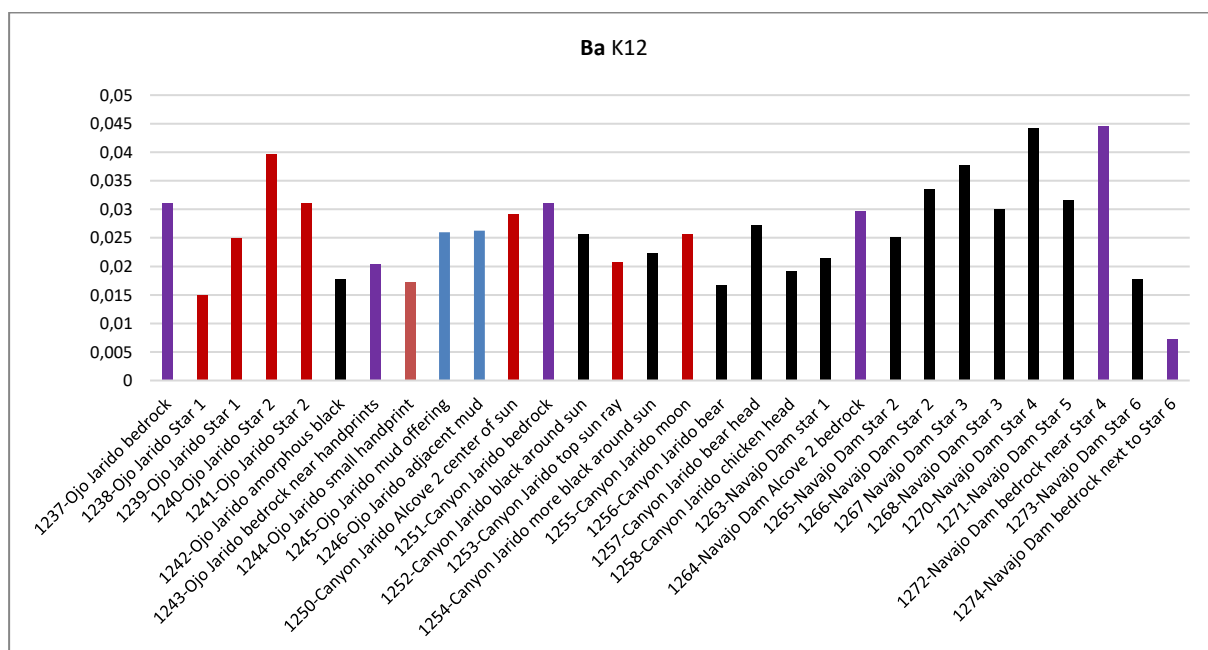
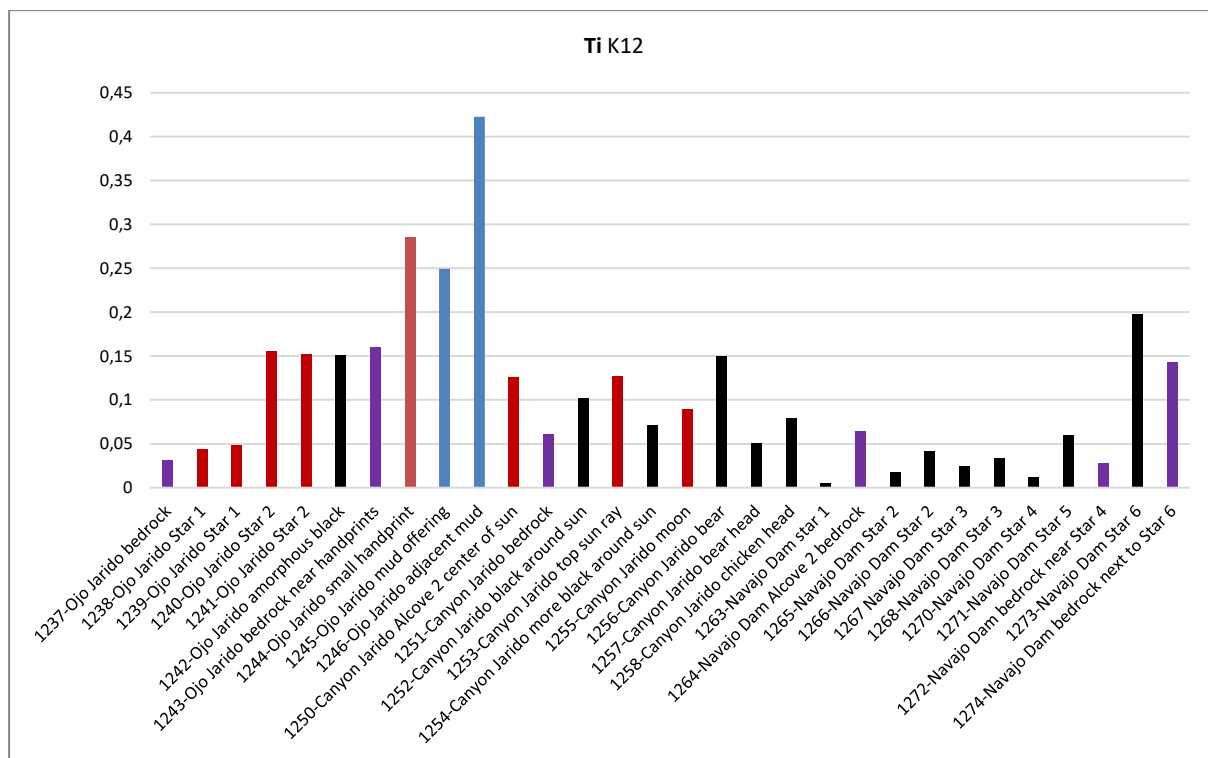


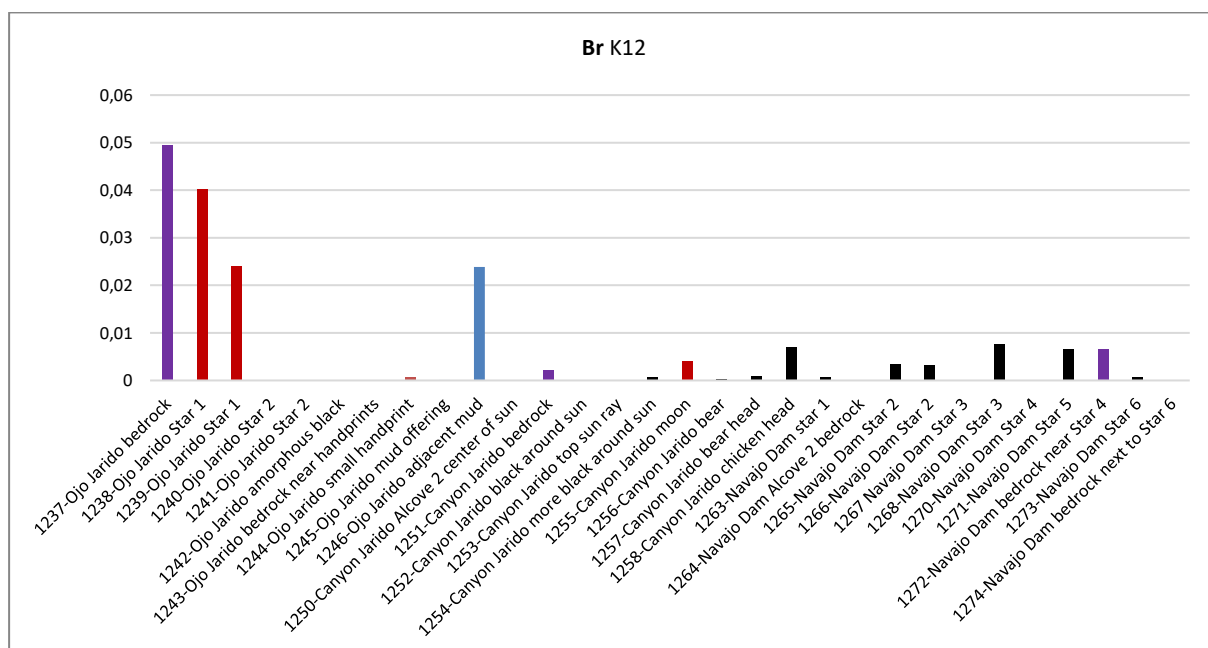
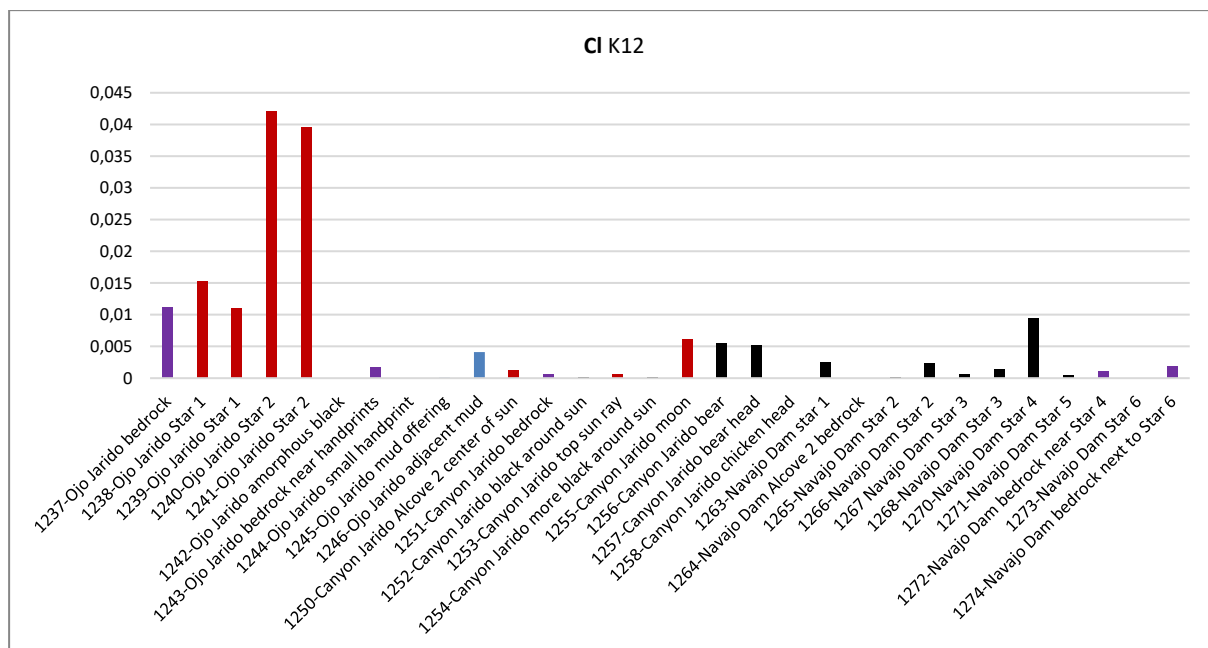


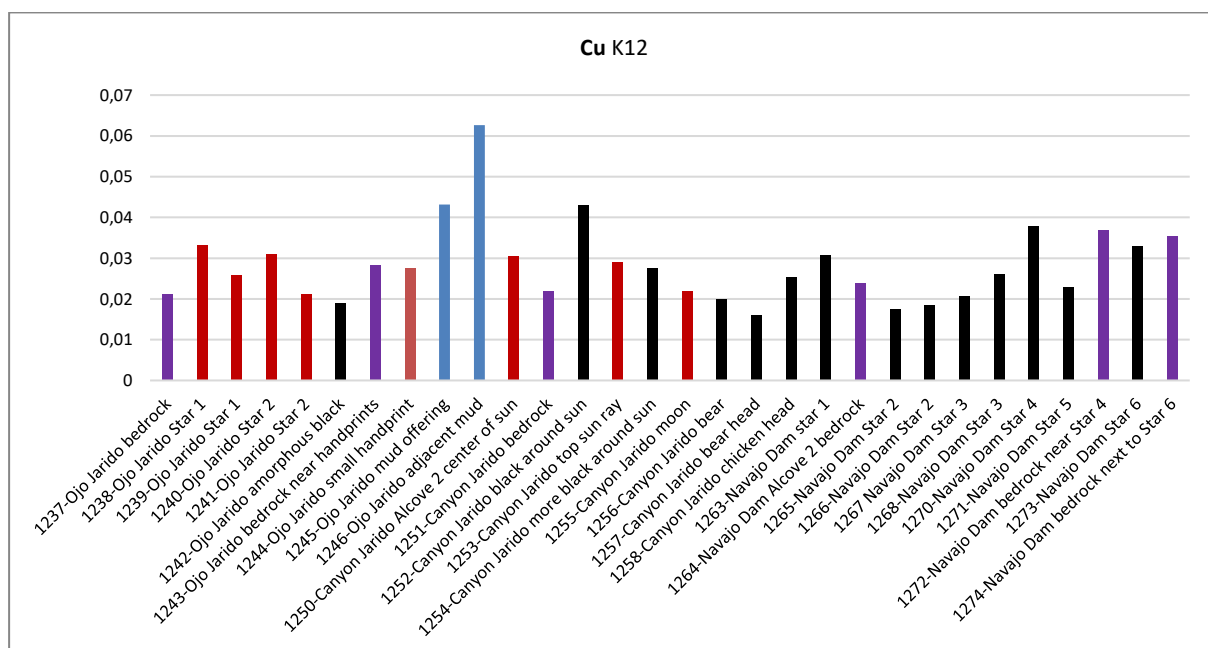
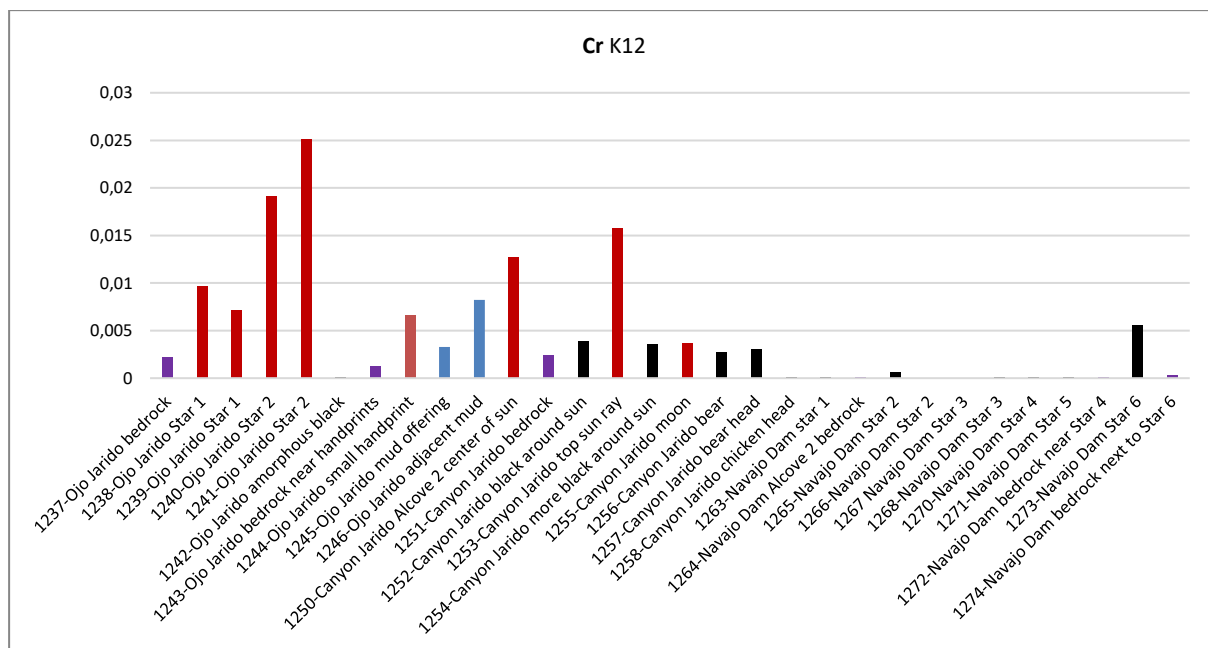


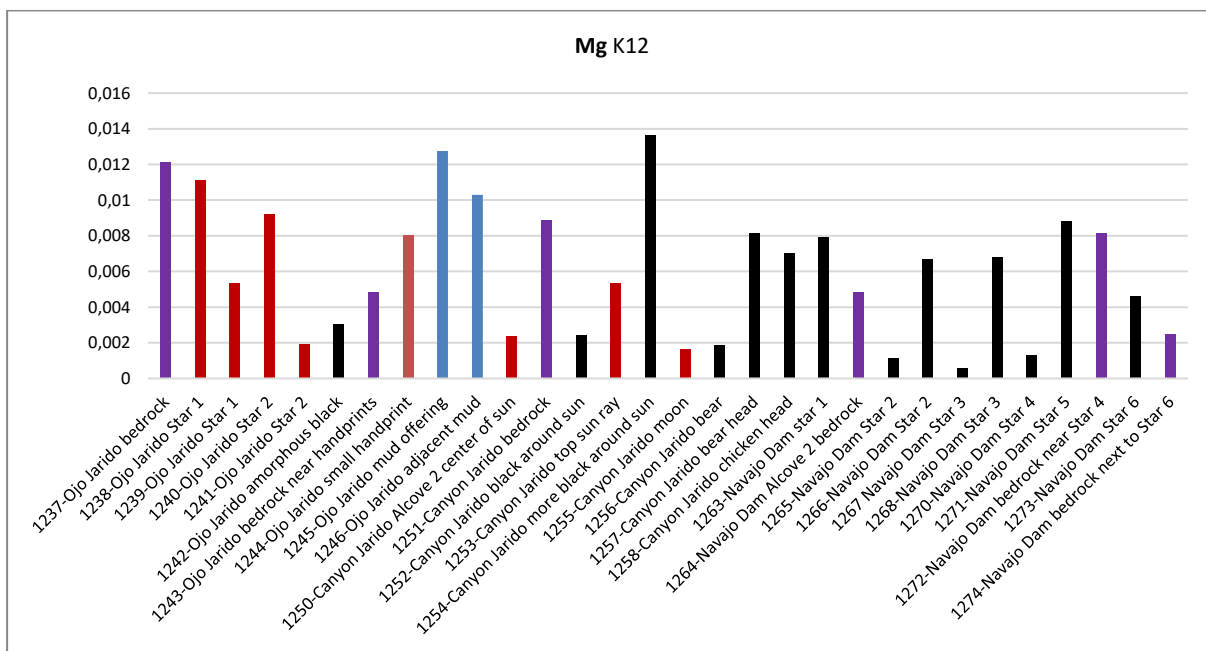
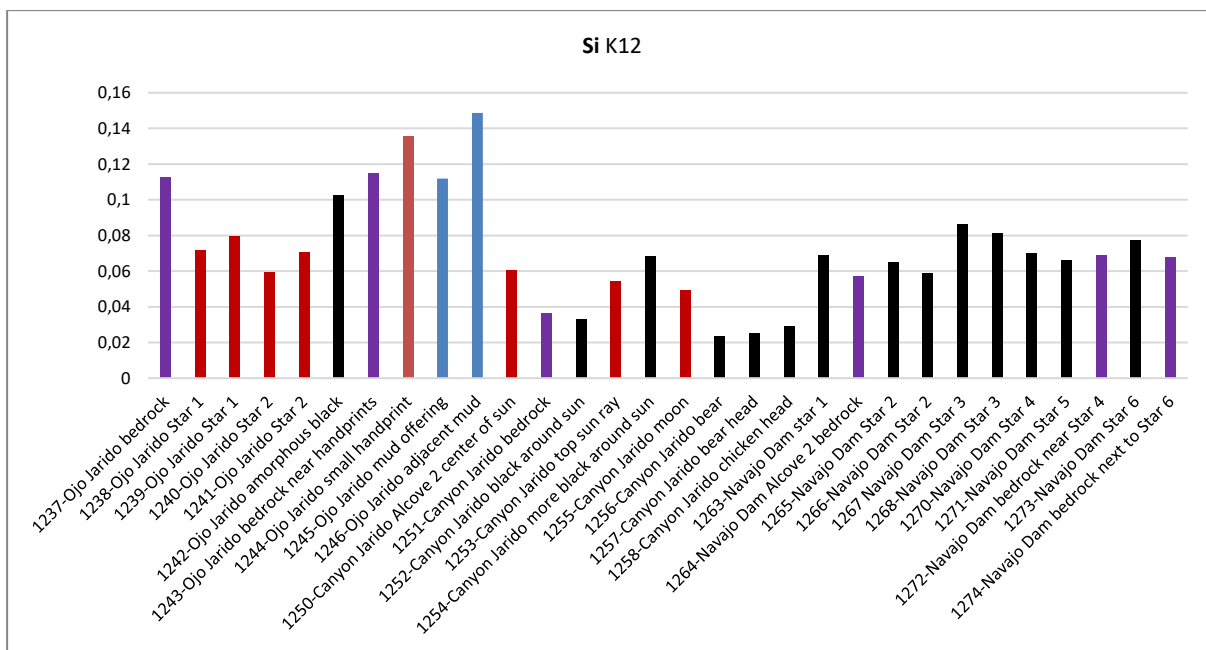


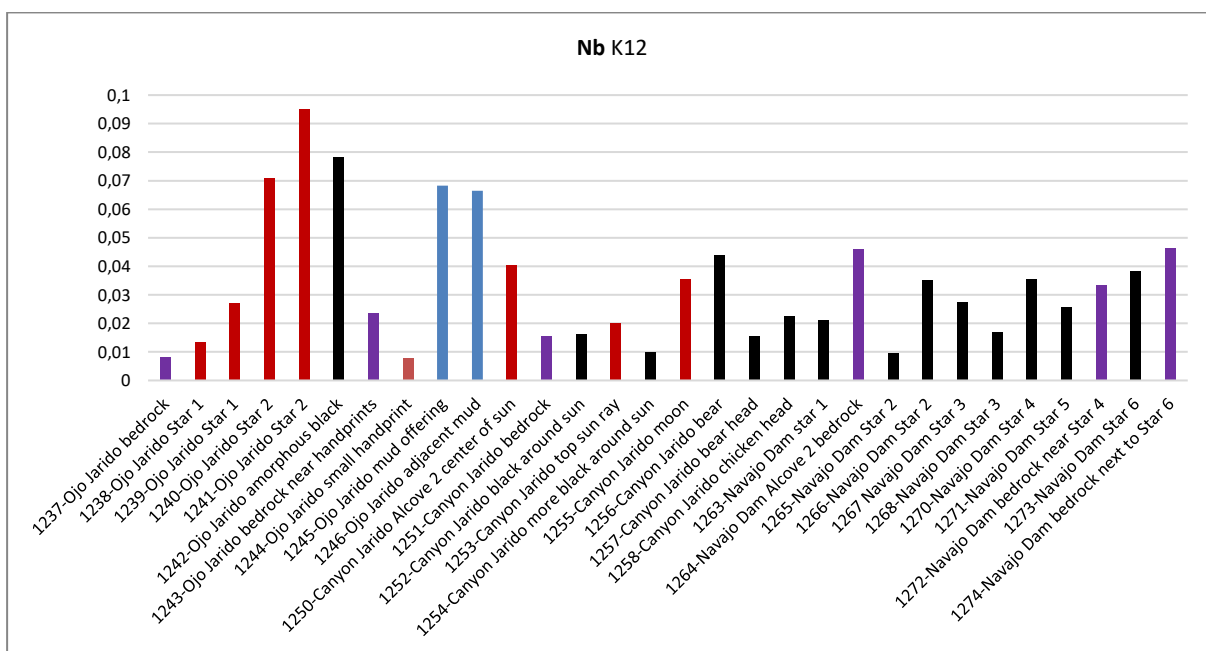
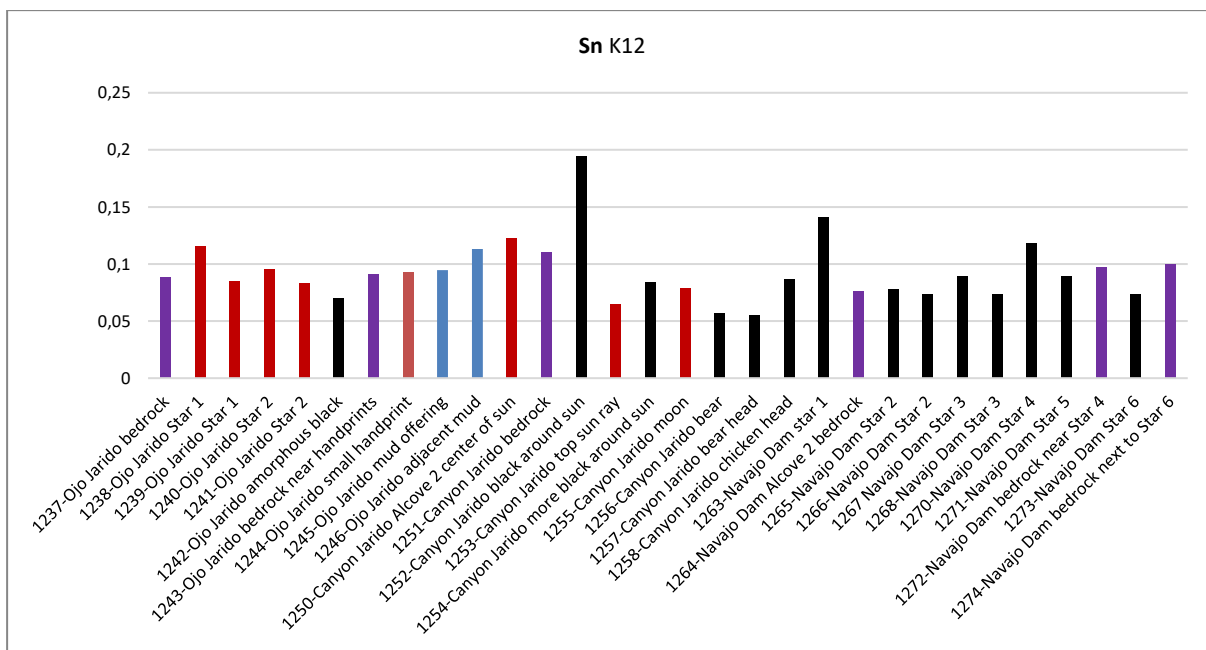


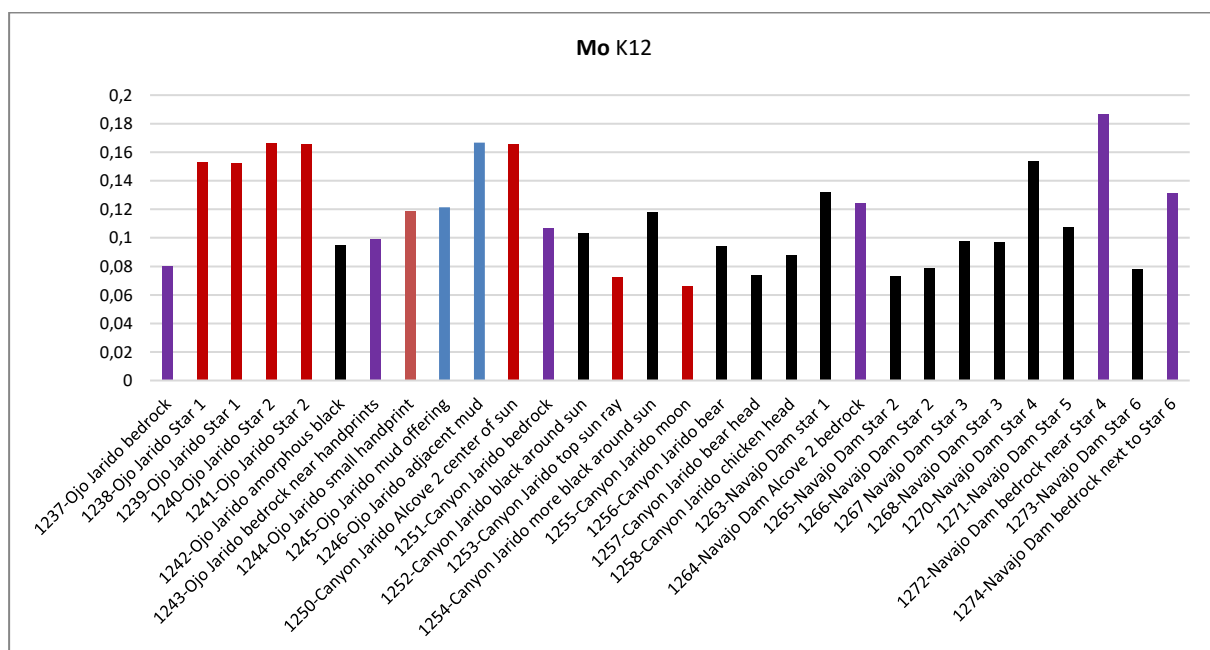
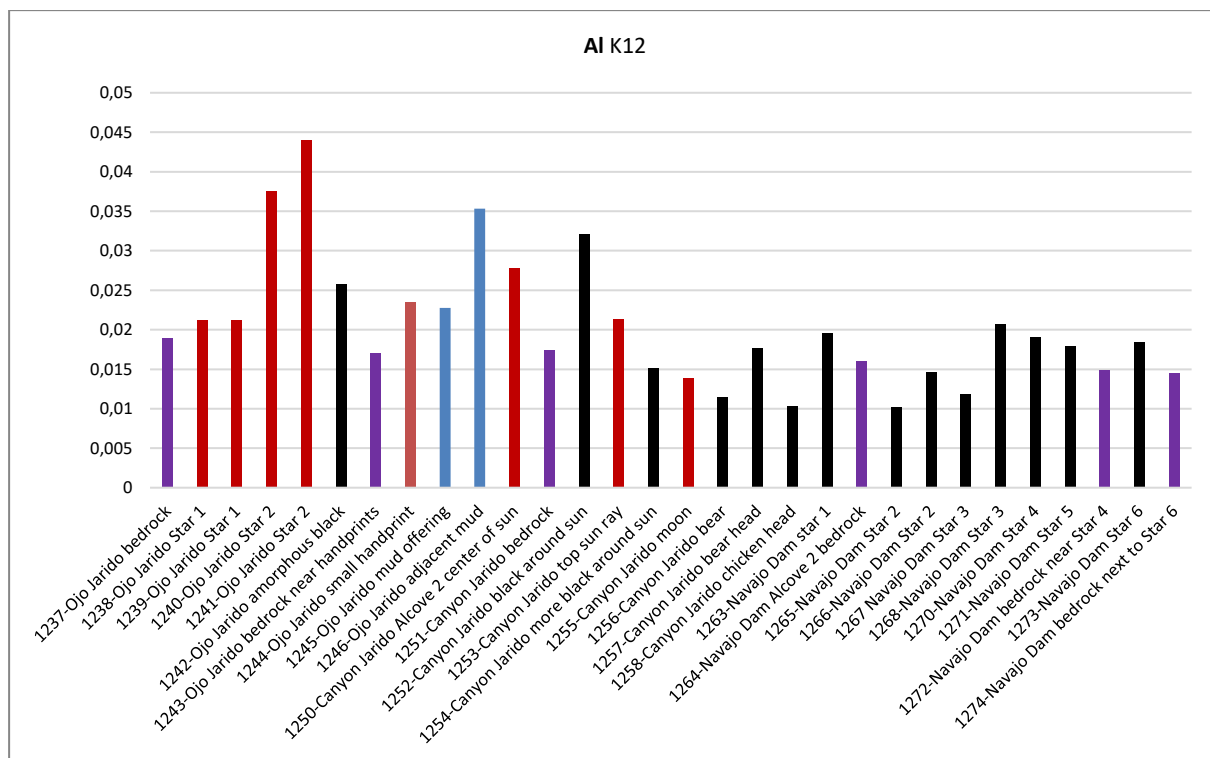












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B) use is limited to not more than 25% of the text of a book or of the items in a published collection of essays, poems or articles;

C) use is limited to no more than the greater of (a) 25% of the text of an issue of a journal or other periodical or (b) two articles from such an issue;

D) no User may sell or distribute any particular anthology, whether photocopied or electronic, at more than one institution of learning;

E) in the case of a photocopy permission, no materials may be entered into electronic memory by User except in order to produce an identical copy of a Work before or during the academic term (or analogous period) as to which any particular permission is granted. In the event that User shall choose to retain materials that are the subject of a photocopy permission in electronic memory for purposes of producing identical copies more than one day after such retention (but still within the scope of any permission granted), User must notify CCC of such fact in the applicable permission request and such retention shall constitute one copy actually sold for purposes of calculating permission fees due; and

F) any permission granted shall expire at the end of the class. No permission granted shall in any way include any right by User to create a substantively non-identical copy of the Work or to edit or in any other way modify the Work (except by means of deleting material immediately preceding or following the entire portion of the Work copied).

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i) The pay-per-uses subject to this Section 14(b) include:

A) **Posting e-reserves, course management systems, e-coursepacks for text-based content**, which grants authorizations to import requested material in electronic format, and allows electronic access to this material to members of a designated college or university class, under the direction of an instructor designated by the college or university, accessible only under appropriate electronic controls (e.g., password);

B) **Posting e-reserves, course management systems, e-coursepacks for material consisting of photographs or other still images not embedded in text**, which grants not only the authorizations described in Section 14(b)(i)(A) above, but also the following authorization: to include the requested material in course materials for use consistent with Section 14(b)(i)(A) above, including any necessary resizing, reformatting or modification of the resolution of such requested material (provided that such modification does not alter the underlying editorial content or meaning of the requested material, and provided that the resulting modified content is used solely within the scope of, and in a manner consistent with, the particular authorization described in the Order Confirmation and the Terms), but not including any other form of manipulation, alteration or editing of the requested material;

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A) any License granted shall apply to only one class (bearing a unique identifier as assigned by the institution, and thereby including all sections or other subparts of the class) at one institution;

B) use is limited to not more than 25% of the text of a book or of the items in a published collection of essays, poems or articles;

C) use is limited to not more than the greater of (a) 25% of the text of an issue of a journal or other periodical or (b) two articles from such an issue;

D) no User may sell or distribute any particular materials, whether photocopied or electronic, at more than one institution of learning;

E) electronic access to material which is the subject of an electronic-use permission must be limited by means of electronic password, student identification or other control permitting access solely to students and instructors in the class;

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15) Miscellaneous.

a) User acknowledges that CCC may, from time to time, make changes or additions to the Service or to the Terms, and that Rightsholder may make changes or additions to the Rightsholder Terms. Such updated Terms will replace the prior terms and conditions in the order workflow and shall be effective as to any subsequent Licenses but shall not apply to Licenses already granted and paid for under a prior set of terms.

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Last updated October 2022

Re: New customer message on January 23, 2026 at 11:37 am

1 message

Garland's <info@garlands.com>
To: tmchrist@umd.edu

Fri, Jan 23, 2026 at 5:43 PM

Hello Tom,

Thank you for reaching out and for your interest in Bobbijo Whitehair's *Sunrise Pictorial*. We appreciate your interest, and we agree it's a beautiful weaving with a lovely depiction of stars!

We'd be happy to approve the use of these images, provided the images are properly credited to the artist and used strictly in a non-commercial context. A high-res version of the primary image is attached. Let me know if I can help with anything else.

Best regards,

Michael

--

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On Fri, Jan 23, 2026 at 11:37 AM Garland's (Shopify) <mailer@shopify.com> wrote:

You received a new message from your online store's contact form.

Country Code:

US

Name:

Tom Christian

Email:

tmchrist@umd.edu

Body:

Hello Garland's,

I'm writing a thesis about star icons in Navajo art. I'm wondering if I can use an image of Bobbijo Whitehair's Sunrise Pictorial in my thesis? I'm happy to pay her for the opportunity. It's a beautiful rug and the morning stars are awesomely depicted.

Thank you,
Tom



WN02397-1.jpg
6324K

Image Permissions

Organization: University of Maryland
Contact: Thomas Christian
Email: tmchrist@umd.edu
Phone: 254-366-5342
Address: 15695 FM 107, Moody, TX 76557

Master's Thesis: Thomas Christian, *Reaching for the Stars*, University of Maryland. Publication date 5/30/26.

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FIELD MUSEUM OF NATURAL HISTORY

By: Jada Whiterock
Jada Whiterock, Assistant Registrar

Date: 9/5/2025

LICENSEE

By: TC
NAME:

Date: 9/5/2025

Re: Image use request

1 message

Ruggles, Clive (Prof.) <rug@leicester.ac.uk>
To: Thomas Michael Christian <tmchrist@umd.edu>

Fri, Sep 5, 2025 at 4:53 AM

Hi Tom,

Happily you've caught me just before I venture over to your side of the pond. This sounds like really interesting work — do please send over any publications down the line!

I don't see a problem reproducing this image. Technically the copyright is shared between Ocarina Books (i.e., me) and John Carlson's Center for Archaeoastronomy, but I haven't been in touch with John for years and I think the Center is long defunct (someone at UMD would surely know). If you like, to cover yourself, just say "reproduced with permission from Ocarina Books Ltd" — I give you that permission as director.

All best
Clive

From: Thomas Michael Christian <tmchrist@umd.edu>
Sent: 04 September 2025 17:25
To: Ruggles, Clive (Prof.) <rug@leicester.ac.uk>
Subject: Image use request

You don't often get email from tmchrist@umd.edu. [Learn why this is important](#)

CAUTION: This email was sent from an **EXTERNAL** source. Think before clicking links or opening attachments.

Hello Professor Ruggles,

I am writing a CRM thesis on Navajo Star Ceilings and would love to reproduce an image found in the book, "Songs from the Sky." It's the map of the Four Corners from Chamberlain and Schaafsma's chapter, "Origin and Meaning of Navajo Star Ceilings."

Is there a formal way to request reproduction of this image? I plan to use it only for the thesis.

By the way, your work has inspired me greatly over the years. With Dr. Paul Zolbrod as Chair, I wrote a dissertation on Star Ceilings in 2012 and relied heavily on this particular book. I'm at it again, examining the elements of these pictographs using XRF and FTIR, and also attempting to look at potential digital preservation techniques to support these artworks' heritage. A life of Star Ceilings!

Respectfully,
Tom Christian

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